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Kathleen R. Murphy
Western Connecticut State University, katiemur11@msn.com

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THE EFFECT OF REFLECTIVE PRACTICE ON
HIGH SCHOOL SCIENCE STUDENTS'
CRITICAL AND REFLECTIVE THINKING

Kathleen R. Murphy

BS Secondary Education: Earth Science, WCSU, 2005
MS Instructional Technology, WCSU, 2008

A Dissertation

Submitted in Partial Fulfillment of the

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Department of Education and Educational Psychology

at

Western Connecticut State University

2014

**THE EFFECT OF REFLECTIVE PRACTICE ON
HIGH SCHOOL SCIENCE STUDENTS'
CRITICAL AND REFLECTIVE THINKING**

Kathleen Murphy, BS, MS

Western Connecticut State University

Abstract

This study investigates the impact of a reflection treatment program on the critical thinking skills and reflection level of high school science students. Although research indicates there is a connection between reflection and critical thinking, there is limited empirical research related to this topic in high school science classrooms. Therefore, this study will attempt to determine whether a reflection implementation not only improves selected domains of critical thinking, but also impacts the level of reflective thinking in high school science students.

The research took place in a small, suburban high school in the northeast from January to May of the year 2013. A sample of convenience comprised of high school students, 9th through 12th grade was used. The study was quasi-experimental in nature, with a pretest/posttest comparison group design using intact classrooms of students. Administration of two instruments measuring the characteristics of dispositions associated with critical thinking and the level of reflective thinking were used. The scores of those students who received the reflection treatment were compared to the scores of those students in the traditional science classroom who did not receive the treatment to determine the impact of this method of delivering instruction. In the multivariate analysis of variance, data revealed that there was a statistically significant difference, ($p = .020$) between the means of the

treatment and comparison groups as measured by the *Reflective Thinking Questionnaire* (RTQ). The reflective practice treatment group scored significantly higher for the subscale of Reflection ($p = .007$) than the comparison group. In the hierarchal multiple regression analysis, the variable of Reflection, as measured by the RTQ, significantly predicted mean scores of Mental Focus ($p = .022$) and Cognitive Integrity ($p = .048$) as measured by the *California Measure of Mental Motivation* (CM3). Findings suggest that students who engage in reflective practice in science class will have significantly higher levels of reflection, as measured by the RTQ, than students who do not. In addition, students' levels of reflective thinking predict their critical thinking dispositions of Mental Focus and Cognitive Integrity.

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APPROVAL PAGE




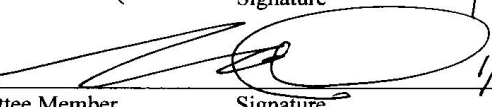
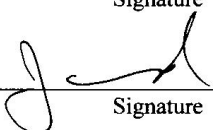
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Doctor of Education Dissertation

THE EFFECT OF REFLECTIVE PRACTICE ON
HIGH SCHOOL SCIENCE STUDENTS'
CRITICAL AND REFLECTIVE THINKING

Presented by

Kathleen R. Murphy, Ed.D.

Marcia A. B. Delcourt, Ph.D. Primary Advisor	 Signature	1/7/14 Date
K. Michael Hibbard, Ph.D. Secondary Advisor Committee Member	 Signature	1/7/14 Date
Jacob C. Greenwood, Ed.D. Secondary Advisor Committee Member	 Signature	1/2/14 Date

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“All the effort in the world won't matter if you're not inspired.” - Chuck Palahniuk,

My inspiration for an education, to pursue a career in education, and to achieve the highest degree in education have come from many different people at many different times throughout my life. It is never expected, yet those comments here, thoughtful discussions there, and moments of reflection at night, stick with you for life. My inspirations are rarely sudden, more often coming in form of memories. Some memories are just of a sentence, a little snippet of words that kept echoing and resounding back every so often. Others recollections are of an entire conversation, an engagement in discourse that changed my philosophy or inspired me to climb that next rung on the metaphorical ladder. It is these people who have inspired me that I would like to acknowledge in my highest educational endeavor, because without them I would never have chosen this path nor made it this far.

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Chad Charon, telling a fifteen-year-old that “Education is the key to success”. Although I only knew you for a summer; the conversation this centered around impressed me so much it made me want to be smart like you.

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DEDICATION

This dissertation is dedicated to my father who is, and will always be the smartest man I know. Growing up, I remember my father's dry wit and sense of humor along with his ability to have an answer to everything. Whenever a conversation centered on something serious; be it political, religious, economical, or philosophical, my dad seemed to be the font of knowledge. When the conversation was not serious, my dad was the one who always had the funny comments. When I first entered higher education, I remember telling myself that one day I hope to be as smart and as educated as he was. Having a father with several graduate degrees, for which he graduated summa cum laude, I was setting the bar high. Although I may not have ever shared that goal with you, Dad, I think I've come pretty darn close. However, no matter the toll of time, I'll always think you're wiser, because, well, fathers just are....

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CHAPTER ONE: INTRODUCTION TO THE STUDY

Recent developments such as Common Core, the Partnership for Assessment of Readiness for College and Career (PARCC), and the Race to the Top (RTT) legislation in American education are impacting educational policy, curriculum, assessment and accountability in the United States (Kyllonen, 2012). With these developments and current changes in national standards, many schools are focusing on the need to develop 21st century skills in today's students. One of the biggest challenges facing educators is how to prepare today's learners for jobs that do not currently exist and which will require proficiency in technologies that have yet to be invented (Dickstein, 2010). If educators cannot define the specific knowledge or skills set that will be required to succeed in a technical and fast-paced global economy, they must teach students to be able to learn from their experiences and be able to make their own decisions rather than rely on those provided by others (Mezirow, 1997). Students who develop a broad set of in-demand competencies, which includes the ability to think critically about information, will be at a greater advantage in their future work and life (Jerald, 2010).

Research indicates that applied skills and competencies for developing 21st century students can best be taught in the context of the academic curriculum, not as a replacement for it (NCREL, 2003; Sawchuck, 2009). Competencies such as critical thinking and problem solving are highly dependent on deep content knowledge and cannot be taught in isolation (Jerald, 2009) but rather as part of traditional core subjects. By incorporating instructional methods within current course curriculum students can be given the opportunities to build and develop skills such as critical and reflective thinking, problem solving skills along with

the real world application of these skills. These proficiencies are important for our students in order to prepare them for success in a complex and demanding world.

Facione (2011) proposes a working consensus of critical thinking as a “purposeful, reflective judgment, which manifests itself in reasoned consideration of evidence, context, methods, standards, and conceptualizations in deciding what to believe or what to do” (p. 22). With the current demands on teachers for improving test scores, students become the victims to an ever-increasing workload with the hopes that if they can produce more work, the result will be higher scores. For many students, this overload of “doing swallows up their learning” (Amulya, 2003, p. 3) and their opportunities for thinking critically. By engaging in reflective practice, students think back on completed work, and analyze procedures, thoughts, and conclusions, as well as assess their strengths and weaknesses. In this form of activity, students are keenly making decisions about the work that has occurred, increasing their effective role in that work, and formulating their own conclusions rather than relying on the judgments or statements of others, thereby improving their critical thinking skills.

The term reflection has many different definitions depending on the context. Most commonly, reflection is defined as a thought occurring in consideration or meditation of a past action or experience (Schön, 1983). When related to learning, Boud, Keogh, and Walker (1985) propose that reflection is an activity where a student is able to recapture his or her experience, think about it, mull it over, and evaluate it. “Reflection is a generic term for those intellectual and affective activities in which individuals explore their experiences in order to lead to new understandings and appreciations. It is this working with this experience that is important in learning” (Boud et al., 1985, p. 19). It is when students bring their ideas to their consciousness that they can evaluate them and begin to make decisions. A

continuous or regular process of this type of thinking is known as reflective practice (Schön, 1983). By providing students the opportunities to consider their experiences in a science class, teachers are allowing them the possibility to increase learning (Amulya, 2003), develop higher order processing skills (Lerch, Bilics, & Colley, 2006), improve achievement (Phan, 2008; Pivovar, 2010), and develop stronger critical thinking skills.

The aim of this study was to measure the effect of a reflective practice instructional method on students' critical and reflective thinking enrolled in core curriculum science classes; standardized high school curriculum classes that embody skills and knowledge considered essential and thus made mandatory for all students. The reflective practice treatment took place over a 16-week period to give the students time to move from lower levels of reflection such as habitual action to higher levels which include critical reflection. This study followed a quasi-experimental research design. A non-randomized control-group, pretest/posttest design was used to compare two different situations; science classes where students engaged in reflective practice and traditional science classes where they did not.

Statement of the Problem

Although much research exists on the benefits of reflection in adult learners, pre-service professionals, and educators (Boud et al, 1985; Herod, 2002; Mezirow, 1997; Schön 1983, 1987), very little research exists on the benefits of reflection for K-12 students. Research on reflection and reflective practice has been, for the majority, carried out with participants at the undergraduate and graduate college levels (Lerch, Bilics, & Colley, 2006; Kember et. al, 1999, 2000; Phan, 2007, 2009, 2010). Valkanova and Watts (2007) explored the role of self-reflection in primary school students ages seven and eight and found that narratives of personal experiences contribute to classroom learning. Recently, Greenwood

(2010) conducted a study with high school science students on the use of reflective portfolios in science as a means to provide students with a medium to develop a repertoire of study and self-regulation strategies. Through statistically significant gains in students' rubric scores, his study found that students benefited from structured goal setting, revision of work, and reflection upon their work. Additionally, the findings supported the use of reflective portfolios to provide students with the necessary mastery goals orientation to reflect upon their current progress towards meeting their academic goals. Therefore, research was needed to investigate if reflective practice allows high school students to improve their critical thinking at this crucial time in their learning development.

Rationale

The purpose of the present study was to assess how reflection assignments in science affect student's critical thinking. Recognizing the role of reflection in learning and becoming familiar with the basic elements of reflective practice will allow students to begin to understand that knowledge is embedded in their learning experiences, and to realize the importance of this knowledge in improving their critical thinking skills. Very often, students are unaware of how their actions are connected to their learning and to the larger schema of contextualization (Raelin, 2002). For many of us, "unawareness does not allow us to be open to new data or information that would help us learn from our actions" (p. 67). McPeck (1990) notes that to think critically, students need something to think about. By engaging in reflection, students are bringing a high level of awareness to their thoughts and actions.

Potential Benefits

According to Mezirow (1997), the essential learning required to prepare a productive and responsible adult for the 21st century must empower the individual to think as an

autonomous agent rather than to act uncritically on the received ideas and judgments of others. By having students engage in reflective activities they are provided with opportunities to consider their actions and evaluate them in the context of various learning activities. Reflective journals assist students in making connections between their learning experiences and relating it to subject matter content (Boud, 2001; Henderson, Napan, & Monteiro, 2004). When students take the time to reflect, they develop the metacognitive elements necessary to think and plan how they may do things differently in the future based on either their success or failures at an activity (Schön, 1987).

If educators can develop an instructional method that imbeds reflection into content area learning activities, they will then have an educational basis that encourages students to become autonomous, reflective, and socially responsible thinkers. Reflective practice activities, such as journals and class summary activities commonly called exit slips, can provide educators with a form of assessment that monitors individual development and progress and can be readily used to inform future instruction (Leigh, 2012). Additionally, written reflections that require students to critique, take objective positions, and to write with logic, coherence and knowledge meet the new advances in learning standards known as Common Core (CCSSI, 2012).

Definition of Key Terms

The following terms are relevant to this study:

1. *Critical Thinking* employs “reasonable, reflective thinking that is focused on deciding what to believe or do” (Ennis, 1991, p. 6).

2. *Exit Slips* are a class summary activity that consists of small slips of paper used for written student responses to questions or prompts teachers pose at the end of a class or lesson (Bafile, 2004).
3. *Learning experiences* are events in the laboratory, or classroom that provide students with opportunities to interact directly with natural phenomena or with data collected by others using tools, materials, data collection techniques, and models (National Research Council, 2006).
4. *Metacognition* is the act of an individual thinking about thinking; monitoring, reflecting on, and regulating his or her own thinking (Flavell, 1979).
5. *Prompts* are sentence stems or questions used verbally by the teacher, in reflective journal writing and on exit slips, that require students to evaluate and extend their understanding of processes, facts or concepts, and examine their existing knowledge before giving a thoughtful response (Department of Education and Training, 2004).
6. *Reflection* is an activity where individuals recapture their experience, think about it, mull it over, and evaluate it. In the context of learning, “reflection is a generic term for those intellectual and affective activities in which individuals engage in to explore their experiences in order to lead to new understandings and appreciations (Boud et al., 1985).
7. *Reflective Journals* are a physical means of recording ideas, personal thoughts and experiences, as well as reflections and insights students have in the process of learning (Chan, 2009).

8. *Reflective Practice* is a continuous or regular process of reflection that involves the learner considering critical incidents in his or her learning experiences (Schön, 1983).

Chapter Summary

With the current changes and developments such as Common Core in national education standards, many schools are focusing on the need to develop 21st century skills in today's students. One of the biggest challenges facing educators is how to prepare today's learners for jobs that do not currently exist and which will require proficiency in technologies that have yet to be invented (Dickstein, 2010). Research indicates that applied skills and competencies for developing 21st century students can best be taught in the context of the academic curriculum. Competencies such as critical thinking and problem solving are highly dependent on deep content knowledge and cannot be taught in isolation (Jerald, 2009), but rather as part of traditional core subjects. By incorporating instructional methods rooted in reflection, within current curriculum, students are provided with the opportunities to build and develop skills such as critical and reflective thinking along with real world application of these abilities. Students who develop a broad set of in-demand competencies will be at a greater advantage in their future work and life (Jerald, 2009). This study used a quasi-experimental, non-randomized control-group, pretest/posttest design to investigate the effect of reflective practice on students' critical thinking by comparing two different situations: science classes that engaged in reflective practice and science classes that did not.

CHAPTER TWO: REVIEW OF THE LITERATURE

To create a context for this study, this review of literature is divided into four sections. The first section introduces the theoretical foundation of constructivism. The second section identifies the theories of reflection and reflective practice and investigates the uses of reflection in educational studies. The third section portrays the views of critical thinking in education and presents related studies in secondary educational settings. The fourth and final section addresses the research and findings that support the components of the reflective practice treatment: reflective journal writing, exit slips, and verbal reflections.

Theoretical and seminal articles and texts were selected from references on readings related to *constructivism, reflection, reflective practice, and critical thinking in secondary education*. Articles and other sources of information were located primarily through a search of the EBSCO database with key terms such as *reflection, reflective practice, reflective journals, reflective prompts, reflective discussions, and critical thinking*. Unless an article was considered seminal research, the selection of literature reviewed was limited to publications within the past 20 years. The researcher selected empirical studies that were conducted in Canada and the United States, as well as in other locations including the United Kingdom, Hong Kong, Lebanon, Israel, and Indonesia.

This review investigated empirical research on the use of reflection in education for K-12 and college level students, student reflective practice, and critical thinking for high school students. Where appropriate, research on the use of instructional methods that included reflective practice, such as journals and exit slips, in the K-12 and undergraduate college level were examined.

Appropriate literature was identified by the following procedures. First, the time period searched ranged from 1990 to 2013 to reflect a profile of the most current research and also because the late 1980s and early 1990s were a time for increasing emphasis on reflection and reflective practice, albeit for pre-service educators and nursing students, due to the work of Schön (1983, 1987), Boud, Keogh, and Walker (1985), and Mezirow (1990).

Second, four online databases, Academic Search Premier, Education Resource Complete, Educational Resource Informational Center, and Professional Development Collection, were consulted using a combination of the following keywords: *reflection*, *reflective practice*, *reflective prompts*, *reflective journals*, *reflective discussion*, and *critical thinking*. These key words were used in conjunction with *student*, *high school students*, and *science* as these terms reflect the phenomenon of the present study and are included in the research questions.

This process identified a total of 12,440 items. Identifying peer-reviewed publications resulted in the elimination to 12,140 items. The search was further limited to include only empirical articles applicable to secondary education or collegiate level student learning. This yielded 737 results. These results were combed through by the reading of abstracts and further limited to research that used reflection or reflective practice as an instructional method and the application of these instructional methods to improving critical thinking within the subject areas of education, nursing, mathematics, and science. This final elimination yielded 47 results. These 47 results were read and annotated by the researcher and 23 articles were selected as appropriate and relevant work to be included in this literature review.

Constructivist Learning Theory

Critical thinking, reflection, and reflective practice in education have a theoretical foundation in the works of Dewey (1933) and Schön (1983), from which the work of others has stemmed. This theoretical foundation, known as constructivism, suggests that people construct their own understanding and knowledge of the world, through experiences and reflection on those experiences. The crucial action of constructing meaning is mental: it happens in the mind. Learning outcomes associated with constructivism include critical thinking and self-awareness of knowledge construction through the incorporation of authentic activity and mindful reflection and epistemic flexibility (Driscoll, 2005). Awareness of one's own thinking and learning processes is a capability commonly called metacognition, which has a place in cognitive information-processing and instructional theory as well. With metacognition and reflexivity, a critical attitude exists in learners that prompt them to be aware of how structures create meaning (Driscoll, 2005). She explains this further by stating, "when learners come to realize how a particular set of assumptions or how a worldview shapes their knowledge, they are free to explore what may result from an alternate set of assumptions or a different worldview" (Driscoll, 2005, p. 401).

Critical Thinking

Educators recognize the importance of critical thinking as a learning outcome necessary to prepare students for success in academia or work beyond high school. However, despite its widely identified need, there is a general lack of consensus regarding the definition of critical thinking (Lai, 2011), which has resulted in many broad uses and different interpretations. Critical thinking has its roots in philosophy and psychology (Lewis & Smith, 1993) with a strand emerging in education (Sternberg, 1986). These diverse

approaches to critical thinking have developed different definitions to reflect their respective fields.

From a philosophical approach, critical thinking or critical thinking skills can be defined as purposeful, reflective judgment, which manifests itself in reasoned consideration of evidence, context, methods, standards, and conceptualizations in deciding what to believe or what to do (Facione, 1990). Working within the philosophical approach is this idea of good thinking, or perfect thought. However, educators argue that this approach does not always correspond to reality (Sternberg, 1986).

From a cognitive psychological approach, critical thinking is defined based on how people actually think versus how they could under given situations (Sternberg, 1986). The types of actions or behavior that the learner exhibits follows this approach to defining critical thinking, which can include a list of skills or procedures performed by critical thinkers (Lewis & Smith, 1993). This definition has been criticized because it reduces a complex orchestration of knowledge into a series of steps or processes (Sternberg, 1986).

Unlike the philosophical and psychological approach, the educational approach to critical thinking is based on years of classroom experience and observations of student learning (Sternberg, 1986). Educators define critical thinking as “reasonable reflective thinking that is focused on deciding what to believe or do” (Ennis, 1991, p. 6). Generating creative ideas, formulating hypotheses, viewing a problem in alternative ways, posing questions with possible solutions, and planning for investigation come under this definition. In education, critical thinking requires the use of reflection, rationality, and decision making as well as identifying it as an important process of problem solving (Ennis, 1991).

Despite the varying approaches on defining critical thinking, researchers agree that there exist three areas which critical thinking encompasses: abilities, dispositions toward critical thinking; and background knowledge (Lai, 2011). This is not necessarily a new idea. Glaser (1941) first proposed that the ability to think critically involves three elements. “First, an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experiences, second, knowledge of the methods of logical inquiry and reasoning and third, some skill in applying those methods” (Glaser, 1941, p. 164).

These three elements are important and interconnected in the process of teaching and developing ways for our students to become critical thinkers. Having the disposition or attitude of mind to think critically sets the stage for improvement in critical thinking ability. A student's dispositions are dimensions of his or her personality which relate to how likely a person is to approach problem identification and problem solving by using reasoning (Giancarlo, 2006). The development of positive attitudes or dispositions towards critical thinking is vital for student success in school and throughout life. Providing students with the background knowledge, most specifically in the form of course content, and then offering authentic situations in which to practice critical thinking improves that ability. Authentic situations are learning experiences that allow for engagement in discussion and debate, decision making, problem solving, and reflection.

Critical Thinking in High School Science

Fraker (1994), conducted an action research study to improve high-school students' critical thinking skills in an integrated earth science geography course ($n = 25$). His study involved three changes to the regular curriculum over a period of four months. These

changes involved the implementation of learning activities that addressed critical thinking skills throughout the curriculum, units which integrated subject matter and incorporated critical thinking, and lastly, assessment techniques that authentically measured critical thinking skills. After exposure to five authentic activities requiring critical thinking and connection to content area, students were assessed using grading rubrics, comparison charts, and written submissions. The effectiveness of improving critical thinking was assessed using a teacher check list of observed critical thinking skills in students, and a pre- and posttest comparison of a problem solving prompt. Upon conclusion of the study and review of the teacher checklists, posttest results, and final projects, Fraker found a qualitatively considerable increase in the critical thinking skills by students. Implications from this study suggest that a change in curriculum content and instructional strategy that moves students beyond the rote recall of facts, and includes authentic problem solving work, is necessary for improving critical thinking in students.

To add to the research on critical thinking, especially in the area of critical thinking attitudes Ben-Chaim, Ron, and Zoller (2000) assessed the dispositions of Israeli eleventh-grade science students ($n = 588$; 328 male, 260 female) towards critical thinking. They focused their study on dispositions according to school type affiliate, scientific level, and gender. School type affiliate is defined as belonging to either rural schools or urban schools, of which are either technical schools or academic schools. Scientific level is the specific subject area the students were enrolled, such as biology, chemistry, physics, or computer science. Of these four science classes students were divided into low academic level, mid-academic level, or high academic level. The California Critical Thinking Disposition Inventory (CCTDI) was administered to establish a baseline and identify possible differences

between student populations from different school types. Their analysis of the CCTDI that was administered and scored indicated that high school students had a positive overall disposition toward thinking critically, which was in accord with similar studies (Facione et al., 1998), and that school type and gender had no statistical significant effect on student's attitude towards critical thinking.

After finding that school type and gender has no effect on students' dispositions toward critical thinking, Barak, Zoller, and Ben-Chaim (2007), in a longitudinal case study, investigated whether or not teaching strategies that promote higher order thinking skills enhanced students' critical thinking in science. Within a pretest/posttest experimental design, high school students were separated into three research groups. The experimental group ($n = 57$) consisted of science students who were exposed to teaching strategies, such as real world problem solving, designed for enhancing higher order thinking skills. The two other groups, science majors ($n = 41$) and non-science majors ($n = 79$), were taught using traditional methods and served as the control groups. The longitudinal study took place over three years, 2002-2005. The study was designed to include two control groups (science and non-science) in order to confirm or refute the possibility that the development of disposition toward critical thinking and critical thinking skills are discipline-dependent. Data collection was based on both qualitative and quantitative methodologies using the *California Critical Thinking Disposition Inventory* (CCTDI) (Facione & Facione, 1992), *The California Critical Thinking Skills Test* (CCTST) (Facione, 1990; Facione & Facione, 1994), semi-structured interviews, and classroom observations. A repeated measures analysis of variance (ANOVA) test indicated that students in the experimental group improved their disposition toward critical thinking significantly more than the subjects in the control groups on the total

CCTDI ($F(2) = 8.62, p < 0.01$), and on four of its subscales: Truth-seeking ($F(2) = 7.41, p < 0.01$), Open-mindedness ($F(2) = 8.08, p < 0.01$), CT Self-Confidence ($F(2) = 4.37, p < 0.02$), and Maturity ($F(2) = 6.40, p < 0.01$). The authors found that by incorporating teaching strategies, such as students' question asking, self-investigating of phenomena, exercising open-ended inquiry-type experiments, and making inferences, students' critical thinking skills and related capabilities were significantly advanced. Implications of this study reinforce the importance of developing higher order thinking skills in science.

In summation, having the disposition or attitude of mind to think critically sets the stage for improvement in critical thinking ability. Providing students with the background knowledge, most specifically in the form of course content, and then offering authentic situations in which to practice critical thinking improves that ability (Fraker, 1994). Findings from the literature review suggest that high school students have a positive overall disposition toward thinking critically regardless of school type (urban versus rural) and gender (Ben-Chaim, Ron, & Zoller, 2000). Incorporating teaching strategies that promote higher order thinking, such as students' question asking, self-investigating of phenomena, open-ended inquiry based labs, and making inferences will lead to the improvement of critical thinking skills (Barak, Zoller, & Ben-Chaim, 2007). Additionally, changes in curriculum content and instructional strategy that move students beyond the rote recall of facts, and include authentic problem solving work, are necessary for improving critical thinking in students (Fraker, 1994).

Reflection and Reflective Practice

Reflection, as it relates to constructivist theory, is a mode of thought articulated by John Dewey (1933) in his book, *How We Think*. He defined reflection as “active, persistent,

and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions to which it tends” (p. 6). Dewey had several criteria for his concept of reflection. First, reflection is a meaning-making process that moves the learner from one experience into the next with deeper understanding of its relationships and connections to other experiences and ideas. Reflection is the thread that makes continuity of learning possible and ensures the progress of the individual. Secondly, reflection is a systematic, rigorous, disciplined way of thinking, with its roots in scientific inquiry (Rodgers, 2002).

Boud, Keogh, and Walker (1985) state “experience alone is not the key to learning” (p. 7). They felt it is necessary to promote awareness in learners of the possibilities for learning and the need for them to take control of their own learning. It is important for educators to draw upon learners’ prior experience and to provide opportunities for them to be engaged actively in what they are learning. Active engagement is done through the process of reflection, a form of response of the learner to experience. Boud, et al. further state, “Only learners themselves can learn and only they can reflect on their own experiences” (p. 11).

According to Boud et al. (1985), the reflective process is a complex one in which feelings and cognition are closely interrelated and interactive. It is not mind wandering or day dreaming, but a purposeful activity directed towards a goal. It is a way of dealing with the vast array of inputs and coping with feelings that are generated. There is a need for students to process the information they have been given, relate this to their previous knowledge, and test their understanding. Boud et al. believe that tests, assignments, and tutorial exercises do not allow students to fully relate to the inputs they receive, which

“inhibits the development of self-organized learning” (p. 11). Reflective activity enables effective problem solving to take place and improves the effectiveness of learning.

Reflective practice is a continuous process that involves the learner considering critical incidents in his or her learning or life experiences. The concept is generally credited to Donald Schön with the publication of his book, *The Reflective Practitioner* (1983). According to Schön, reflective practice involves thoughtfully considering one's own experiences in applying knowledge to practice while being coached by professionals in the discipline. Schön argued that the model of professional training that relied upon filling up students with knowledge then sending them out into the world of practice was inappropriate in a fast-changing world. A reflective practice model would enable learners and novices within a discipline to compare their own practices with those of experienced practitioners, thus leading to development and improvement (Schön, 1983). This idea, although initially applied to adults, is easily transferrable to the high school level whereby students engage in a form of reflective practice and the teachers are the coaches or experts in the field.

Other theorists have connected reflection to constructivism and have stressed its importance in education. Bruner (1966) suggested that by having students reflect on a difficulty, think about what occurred, and evaluate the outcomes, they might be helped to increase their conceptual understanding and long-term knowledge retention. Marzano (2007) defined the reflective process as a set of interacting instructional strategies used to help students actively process content during critical learning experiences. In this manner, reflection is an intentional act, engaging students in questioning their own thinking to construct understanding of it. He suggested that students use reflection as a means to identify

points of uncertainty, levels of understanding regarding content, and preconceived ideas that were accurate as well as ones that were inaccurate.

Reflection in Education

Although reflection is widely written about by many theorists (Boud et al., 1985, Bruner, 1966; Marzano, 2001, Schön, 1983) and its effectiveness has been researched in adult pre-service professions, (Cormish & Jenkins, 2012; Kember et al., 2006; Osterman, 1990; Phan, 2009; Schön, 1987; Taylor-Haslip, 2004; Uline, Wilson, & Cordry, 2004) very little research exists on its use in the K-12 education setting. Many of the K-12 studies are qualitative action research (Pivovar, 2010; Valkanova & Watts, 2007), mixed methods research (Greenwood, 2010), or quasi experimental without comparison groups (Nelson & Drake, 1997).

Although not conducted at the K-12 level, Lerch, Bilics, and Colley (2006) performed an action research study on undergraduate college students enrolled in algebra, occupational therapy, and general education which gives insight to the use of reflection on non pre-service undergraduate students. In their study, specific writing assignments were imbedded in their courses to encourage metacognitive reflection in order to increase learning and to develop higher order processing skills. The study was divided into three segments, with each author researching the use of reflection on his or her own class. Sample sizes were not provided. In the first segment of the study, involving the first year algebra students, the researcher found that through reflective writing assignments, students were able to identify why the learning was important to them, recognize specific areas of difficulty, and change their emotional response to the course. In the second segment of the study, involving students in a general education course, the researchers found that by responding to reflective prompts students

were able to think about their own learning process, and were able to synthesize information from readings and class discussions. In the third segment of the study, involving online occupational therapy students, the researcher found that through guided reflections about the readings, students moved from simple recall of information to more complex levels of comprehension and synthesis, and finally to a knowledge utilization level and self-system thinking. Self-systems thinking is the integration of attitudes, beliefs, and emotions which determine motivation and attention (Marzano, 2001). In all three segments of the study, students' writing samples were analyzed using Marzano's two-dimensional model of knowledge to identify how students' thinking developed over time. The authors, through their own analysis of students' work, found that the reflection prompts generated results at various levels of thinking. As the study progressed, self-systems thinking, emotional response, and a full range of cognitive systems were seen in the students' reflections along with evidence of higher level functioning. Implications for this study indicated that reflection on work, over a period of time, led to growth in students' cognitive and critical thinking.

Similarly at the undergraduate level, Phan (2009) tested a conceptual model that included deep processing strategies, effort, mastery and performance approach goals, reflection, and critical thinking. Casual modeling procedures were used to explore the direct and mediating effects of these theoretical orientations on students' academic achievement and learning. The population sample for this study consisted of undergraduate college students, ($n = 347$; 151 women, 196 men). Phan found that reflection had a direct effect on academic achievement ($\beta = .31, p < .001$), and on academic learning ($\beta = .26, p < .05$). There was a strong effect on reflection by mastery goals ($\beta = .67, p < .001$), followed by

performance-approach goals ($\beta = .21, p < .001$) and effort ($\beta = -.11, p < .05$). This study showed that reflection, critical thinking, and performance-approach goals influenced academic learning. Reflection and critical thinking, similarly, influenced academic achievement. Implications are, first, reflection and critical thinking encourage the cultivation of meaningful learning, the development of skills such as articulation, and the theorization of new knowledge. Phan concluded, “Students who see learning as having the initiative and capability to reflect and to generate new theoretical knowledge are more likely to succeed academically” (2010, p. 308). Secondly, students who pursue performance-approach goals are, in general, more likely to adopt the use of reflection, as this process may facilitate better understanding and analysis of knowledge and skill improvement. Likewise, the notion of learning to master new skills and knowledge for interest and skill development may also help students to practice the art of reflection. Reflection, in turn, may enable students to articulate their thoughts, current knowledge, and experience, which ultimately, leads to academic achievement and learning. Third, the evidence obtained emphasizes mastery and performance-approach goals, reflection, and critical thinking as determinants of students’ learning and academic achievement.

The use of reflection in K-12 education. At the K-12 education level very little research exists for the use of reflection, however, three recent studies exist. At the primary school level Valkanova and Watts (2007) explored the role of digital video in promoting oral language development through reflective self-learning in seven and eight year old ($n = 30$) primary school students. In this qualitative study, the researchers examined children’s spoken stories produced as voiceovers to fragments of their own video clips. In the spoken voiceover, the students are tasked with explaining their thoughts about their own learning

experiences, a form of self-reflection. In an effort to understand the nature of children's self-reflection, data were analyzed by discourse and narrative analysis. Results from this study suggest ways in which oral and visual self-reflective narratives of personal experience may contribute to classroom domain learning.

At the middle school level, Thomas Pivovar (2010) conducted an action research study at a Native American school with Native American students ($n = 6$) in his 8th grade social studies course. In this study, students were asked to complete a Likert-scaled survey on their level of self-reflection prior to the study along with a content-based, teacher made exam. The treatment consisted of students being asked to reflect on their thinking daily, at the start of each class, with opportunities to share their thoughts verbally during the class. Students were given the self-reflection survey and the content-based exam again upon conclusion of the treatment. Pivovar found a qualitatively positive shift towards agree (33%+) and strongly agree (16%+) on the Likert survey questions that asked students if they thought about what they were learning, understood the process as they were learning, and followed directions. Mean scores on the content test showed improvement in achievement by an average of 10%. Neither a full statistical analysis of test scores, nor an assignment of a comparison group was carried out with this study. Although the sample size was small, the implications indicated that there was an academic and metacognitive benefit to reflection and that follow up studies were needed.

At the secondary level, Greenwood (2010) conducted a study with high school science students ($n = 158$) on the use of reflective portfolios in science as a means to provide students with a medium to develop a repertoire of study and self-regulation strategies. Based on rubric scores, he found statistical significance ($p < .01$) in that, over time, students

benefited from structured goal setting, revision of work, and reflection upon their work. These findings support the use of reflective portfolios to provide students with the necessary mastery goals orientation to reflect upon their current progress towards meeting their academic goals. This study also suggested that the use of reflective portfolios allowed students to consider behavior changes necessary to meet their goals and provided a framework for dialogue about self-regulation and performance with their teacher.

Review of Effective Methods of Reflective Practice

Existing research indicates that reflection is beneficial in teaching and in learning processes, as it enables students and educators alike to think critically about their own learning and professional development. The ultimate outcome of reflection is the development of specific skills that may assist students to become more critical (Phan, 2007). In order to implement reflective practice as a means of developing student learning, reflection, and critical thinking, it is essential that reflection activities are designed to be both retrospective and prospective: students considering their learning experience in order to influence future action. Effective reflection activities are those that are linked to particular learning objectives of the class, are guided by the instructor, occur regularly throughout the course, allow feedback and assessment, and include opportunities for clarification of values (Hatcher, 1998). Eyler and Giles (1999) found that the more rigorous the reflection in a course, the better the learning, including academic outcomes such as deeper understanding and better application of subject matter, increased complexity of problem solving, openness to new ideas, and critical thinking skills. Additionally, when reflective activities are integrated into class activities and discussions, and appear on exams, students report higher

levels of satisfaction with the course and greater academic gains from the experience (Hatcher, 1998).

Kember et al. (1996) discovered that students needed an introduction to, and feedback upon, reflective writing as it differed from other types of writing required for academic courses. The authors establish that in order for reflection to be taken seriously it needs to be an integral part of the course and perceived as an intrinsic component by the students (1996). Moreover, reflective writing should be examined reasonably frequently when students are new to reflective writing, and most importantly, provisions for frequent feedback on what is written must be provided (Kember et al., 2006).

Examples of reflective practice methods vary. However, most commonly used methods for reflective writing are journals and small summary submissions, such as exit slips or short postings (Hatcher, 1998; Eyler & Giles, 1999). In addition, verbal reflections in the form of class discussion or conversations are considered a viable reflective practice method (Henderson et al., 2002; Jindal-Snape & Holmes, 2009; Pivovar, 2010).

Reflective Journals

Reflective journals are tools designed to promote reflective, self-directed learning in students and to encourage them to think critically on the process of learning and development over time. It is based on the premise that writing contributes to deeper learning and engagement with the content area, since it gives students the opportunity to clarify and reflect upon their thinking (Harris et al., 2007). This idea was later supported by Bean (2011) when he stated, “the regular habit of journal writing can deepen students’ thinking about their course subjects by helping them see that an academic field is an arena for wonder, inquiry, and controversy rather than simply a new body of information” (p. 127). A reflective journal

can be maintained regularly over time, and may describe events, experiences or issues associated with the learning.

Journal writing has become a widely used strategy for promoting reflective learning among students (Boud et al., 1985; Boud, 2001; Chirema, 2007; Henderson, Napan, & Monteiro, 2004; Taylor-Haslip, 2009; Uline, Wilson, & Cordry, 2004). Reflective writing helps the student in explaining and clarifying complex thoughts or arguments. Lukinsky (1990) promotes the use of journal writing as a form of reflective withdrawal, where he stresses the importance of a pause in the learning activity to allow the individual to reflect upon what is being unnoticed, overlooked, or avoided in the past and thereby makes changes in the future. Kember et al. (1996) stressed that the format for reflective writing and the periodicity of requiring students to complete journal entries should be a function of the course. In their study, clinical educators were provided with small notebooks for handwritten journal entries. The purpose of this was to move students away from more formal, academic report writing towards a more personalized entry. The authors claimed that “provision of the notebook helped to show that journal writing was different from other forms of academic writing” (Kember et al., 1996, p. 336). Reflective writing should not exist outside the scope of the student learning objectives and is most effective when integrated into the course as curriculum criteria.

According to Boud (2001) the journal is the place where events and experiences are recorded, as well as the occasion in which they are processed and re-formed. It provides the opportunity for students to work with events and to make sense of their experiences, recognize the learning that results, and it leads to a foundation for new experiences that will in turn incite new learning. Journal writing is a useful instrument for promoting reflection,

however, great care must be taken into consideration in how they are assessed (Boud, 2001). In fact, they should be viewed separately from other graded assignments.

In a study conducted by Uline, Wilson, and Cordry (2004) reflective journals proved to be valuable in assessing the most significant learning experiences of secondary pre-service education students ($n = 86$). The authors found that acquiring feedback through reflective journals can shed light on the effectiveness of a theory and practice curriculum and the analysis of responses in the journal entries can identify topics that should receive more emphasis.

Henderson, Napan, and Monteiro (2004) conducted a qualitative case study to examine the application of reflective learning journals online. The purpose of applying reflective journals was to develop critical thinking, help students integrate theory, practice, and experience and relate presented theoretical knowledge to real life situations. In a first year undergraduate information management course, students ($n = 53$) were required to complete 10 reflective journal entries in an online discussion board that provided two way communication with the students and the lecturer. The individual reflective journal entries were based on face to face learning modules or readings, where students were asked to reflect on an aspect of their own experience and to project how the learned knowledge could be utilized in the future. The journal entries were graded according to the level of reflection on a 5-point scale, and feedback was provided in the form of comments and encouragement. Using qualitative analysis, the authors found that, over the course of 12 weeks, most of the students improved on their journal writing, this method of learning was effective, and overall student feedback on journal writing was favorable. As a consequence, students gained deeper understanding of the material learned, managed to contextualize it, and developed

meaningful professional relationships with their teacher. Implications suggest that “journal writing is an intentional reflective design strategy that can be used to augment the traditional face to face learning environment to facilitate the integration of what can often be purely academic work” (Henderson, Napan, & Monteiro, 2004, p. 362).

A few years later, using a purposive homogeneous sample of part-time post registration nursing students ($n = 42$), Chirema (2006) undertook a qualitative case study to examine the use of reflective journals in promoting reflections and learning. Data were collected from 42 reflective journals and 20 interviews. Following the process of analyzing the journals for level of reflective thinking, the students were placed into one of three groups, non-reflector, reflector, and critical reflector based on their journal entries. Five participants were randomly selected from each group for interviews. The aim of the interviews was to obtain students’ views on reflection and their experience of writing a reflective journal. Approximately two thirds of the students were able to demonstrate varying levels of reflecting and critical reflecting. Mainly positive views were expressed regarding the value of the journals. Chirema’s findings suggest that student writing can be used as evidence for the presence or absence of reflective thinking. Evidence also suggests that journals are a useful tool for promoting reflecting and learning, although some students appear to benefit more than others.

Reflective Prompts

Several studies have involved the use of reflective prompts to guide students’ reflective writings. In a classroom study involving middle school science students, ($n = 178$), Davis (2003) investigated ways of prompting students for reflection. In her study, two types of prompts were contrasted. The first type, called generic prompts, represented an open

ended view that asking students to stop and think will encourage reflection. For example, students were asked to complete the statement “Right now I am thinking...” The second type, called direct prompts, assumed that a generic request for reflection was insufficient and that students should instead be provided with hints indicating potentially productive directions for their reflections. An example of a direct prompt was, “To do a good job on this project I need to...” Davis found that generic prompts that required more reflective thinking elicited more productive kinds of activities than the directed prompts. Students who received generic prompts cited more ideas ($M = 1.696$ ideas cited per writing) than did the students who received directed prompts ($M = 1.163$); $t(87) = -2.448, p < .001$. Students who received directed prompts gave non-reflective types of responses significantly more often than did those in the generic prompt group; $F(1, 89) = 14.00, p = .003$. Students in the generic prompt condition developed significantly more coherent understandings of science ($p = .008$) than did students who received directed prompts. Implications from this study suggest that by allowing students to take control of their own reflection, teachers help them make the experience more concrete. Generic prompts that foster reflective thinking appeared to be a more successful instructional strategy in comparison to the particularly directed prompts.

At the undergraduate level, Taylor-Haslip (2004) explored the use of guided reflective journals in helping nursing students achieve the goal of assuming more challenging nursing roles. These roles called for greater levels of responsibility and required nurses to think critically rather than rely on the guidance of others. The sample population consisted of a total of 30 licensed practical nurse students (28 female and 2 male) ranging in age from their mid-20’s to their mid-50’s. Each student was given a journal and a prompted weekly writing assignment that would compel him or her to reflect on his or her practice in the

clinical setting and encourage him or her to be better prepared for future experiences. The journals were collected and were evaluated on the basis of the level of reflective thinking to be found in the writing and provided feedback on how the level might be improved the next time. The level of reflective writing was evaluated on a hierarchical range of one to four, with one being “descriptive” and four being “critical reflective.” Results of the study indicate that most students showed clear evidence of being able to use their instructor’s feedback to increase their level of reflection found in their journal writing. Additionally, the use of guided reflective journals points to a positive influence on overall student progress. Evidence from the study suggests that as students improve their level of reflective writing, exam grades and clinical performance improve as well. The author posed that “through reflection, students become more attuned to themselves and begin to develop an awareness of the temporary limitations and potential applications of their knowledge base” (Taylor-Haslip, 2004, p. 36).

Employing a framework of making connections often used in reading comprehension, Correia and Bleicher (2008), carried out an exploratory interpretive research study to investigate how students make sense of their service learning experiences through their reflective journals. The investigation was narrowed further to examine the types of connections students made to self, similar settings, and the world. Undergraduate university students ($n = 87$) used electronic journals in which they composed entries all semester in response to four writing prompts to which instructor feedback was provided. Students reported that they found the feedback helpful in guiding them in the next round of reflection writing. Journals and comments were accessible only to the individual students and the instructor. The authors found that students made connections to their personal ideas, beliefs,

and attitudes. They discovered that particular words, phrases or prompts, and reflection markers are useful in teaching students how to write reflections. Among others, implications from this study suggest that developing a set of writing prompts that address course objectives and include reflection prompts helps facilitate student's reflective journal writing.

Exit Slips

Exit slips are written responses to questions or prompts that teachers pose at the end of a class or lesson that require students to think critically. These quick, informal assessments enable teachers to quickly assess students' understanding of the material and connections they are making. For students, exit slips can enhance meta-cognitive skills, help them reflect on what they have learned, and express what or how they are thinking about the new information (Fisher & Frey, 2004). Used regularly, they can generate increased thinking in the classroom. "They can invite students, and by proxy the teacher, to become active, critical listeners to discussion and, as a result, more reflective thinkers" (Leigh, 2012, p. 189). Exit slips offer students an opportunity to process ideas, to question, to think over what has been shared and discussed in class and then jot them down rather than letting these ideas or questions just simply dissolve. Exit slips are ideal for capturing individual bursts of thinking; just when students think they cannot be heard or have nothing to share; exit slip writing can capture their ideas as they occur (Leigh, 2012). Moreover, they can lead to self-reflective thought, which can strengthen individual interpersonal communication skills (Bafile, 2004). As Buehl (2003) points out, exit slips are more than just places to jot down ideas. They can encourage the synthesizing of ideas, which is critical in comprehending new material or experiences.

In a 14-week qualitative study, Leigh (2012) investigated the use of exit slips in two literacy courses of undergraduate pre-service and graduate in-service level education students ($n = 44$). The purpose of the study was to examine how exit slips supported students. Exit slips with broad reflective prompts were presented to students at the beginning of the class and collected after class. Positive, affirming feedback was provided on each slip. Using grounded theory to analyze data and address categories and patterns that emerged in the exit slips, the author found that exit slips serve as a vehicle for review of material, help absorb new information, encourage divergent thinking, and promote self-expression. Exit slips provided a safe place to respond, to ask questions, or to make comments that a student may not have shared otherwise.

Verbal Reflections

An alternative strategy to be used in conjunction with, or as a substitute for, written reflections is the use of verbal reflective techniques such as reflective questions, reflective dialogue, and after-action reviews (Mezirow, 1990). Each of these techniques uses dialogue to facilitate cycles of reflection and action. The reflective component encourages each individual to share thoughts, feelings, and reactions, as well as an analysis of his or her experience (Plack, 2005). The instructor poses questions that encourage students to think more broadly and more deeply about his or her learning experience. The challenge is to encourage students to think critically, uncover assumptions, consider multiple perspectives, and explore multiple strategies before coming to a conclusion.

Studies evaluating the effectiveness of reflective group discussions and students' perceptions toward reflective group discussions in comparison to reflective writing approaches are comparatively few. Henderson, Napan, and Monteiro, (2004) suggested that

semi-structured reflective group discussions enhanced students' enjoyment and perceived learning. Jindal-Snape and Holmes (2009) identified conversation as a beneficial method of reflective practice, especially when reflective conversations occurred with a mentor or reflective supervisor and as exchanges between peers or communities of practices. As described earlier, Pivovar (2010) used reflective discussions daily at the start of every class to determine if reflective practice would improve student's achievement. Results implied that there was an academic and metacognitive benefit to reflection.

Yacoubian and BouJaoude (2010) used a pretest/posttest control group design with sixth grade science students ($n = 38$) and focused mainly on qualitative data. After each science laboratory session students were asked questions based on the nature of science. Students in the experimental group were given open-ended questions that engaged them in reflective discussions with each other. Students in the control group were given content based questions and the participated in discussion only on the results of the lab activity. Data sources for this study included an open ended questionnaire used as a pre and posttest, answers to the questions given to the experimental group, transcribed video of the reflective discussions from the experimental group, and semi-structured interviews. Results indicated that explicit and reflective discussions following inquiry based laboratory activities enhanced students' views on the target nature of science aspects more than implicit inquiry-based instruction.

More recently, a qualitative research study was conducted by Tsang (2011) to determine perceptions of third year undergraduate students ($n = 65$) on in-class reflective group discussions as a critical reflective approach. Tsang found that students welcomed the inclusion of reflective group discussions into their curriculum, not as a substitute for, but

rather as a complementary strategy to enhance reflective writing. Additionally the author found that the key benefits of reflective group discussions perceived by students included peer learning, peer and/or tutor support, and multi-perspective critical thinking.

Research supports the positive impact of reflection on student achievement (Phan, 2009; Pivovar, 2010), academic learning (Phan, 2009), improved cognitive and critical thinking (Lerch, Bilics, & Colley, 2006), and mastery goal orientation (Greenwood, 2010), but limited sources of information exist connecting this type of learning to high school science and critical thinking. By embedding reflection and reflective practice elements in science content through reflective journals, exit slips, and verbal discussions, students are provided with the ability to construct scientific meaning rather than simple rote recall of facts, to increase learning (Amulya, 2003), to develop higher order processing skills (Lerch, Bilics, & Colley, 2006), to improve achievement (Phan, 2008; Pivovar, 2010), and to develop stronger critical thinking skills.

Research Questions and Hypotheses

After a review of relevant literature the following research questions emerged. By using a systematic approach, this study addressed the following research questions (RQ) and tested the non-directional hypotheses (HYP):

RQ1: Is there a significant difference in critical thinking as measured by each of the mean scores on the *California Measure of Mental Motivation* (CM3) subscales (mental focus, learning orientation, creative problem solving, cognitive integrity, and scholarly rigor) of high school science students who participate in a reflection program on classroom learning experiences and those who do not?

HYP1: There will be significant difference in critical thinking as measured by each of the mean scores on the CM3 subscales (mental focus, learning orientation, creative problem solving, cognitive integrity, and scholarly rigor) of high school science students who participate in a reflection program on classroom learning experiences and those who do not.

RQ2: Is there a significant difference in the level of reflective thinking as measured by each of the mean scores of the *Reflective Thinking Questionnaire* (RTQ) subscales (habitual action, understanding, reflection, and critical reflection) in high school science students who participate in a reflection program on classroom learning experiences and those who do not?

HYP2: There will be significant difference in level of reflective thinking as measured by each of the mean scores of the RTQ subscales (habitual action, understanding, reflection, and critical reflection) of high school science students who participate in a reflection program on classroom learning experiences and those who do not.

RQ3: To what extent and in what manner do each one of the variables reflection and critical reflection, as measured by the RTQ, significantly predict the critical thinking variables of mental focus, cognitive integrity, and scholarly rigor, as measured by the CM3, after accounting for the variance in program participation?

HYP3: The variables of reflection and critical reflection, as measured by the RTQ, will either individually or together, significantly predict the variables mental focus, cognitive integrity, and scholarly rigor, as measured by the CM3, after accounting for the variance in program participation.

Chapter Summary

A constructivist approach is the basis for reflection and reflective practice. The fundamental underpinnings of critical thinking, reflection, and reflective practice in education have a theoretical foundation in the works of Dewey (1933) and Schön (1983), from which the work of others has stemmed. Educators recognize the importance of critical thinking as a learning outcome necessary to prepare students for success beyond high school. In education, critical thinking requires the use of reflection, rationality, and decision making as well as identifying it as an important process of problem solving (Ennis, 1991). Providing students with the background knowledge and then offering authentic learning experiences that allow for engagement in discussion and debate, decision making, problem solving, and reflection improves critical thinking ability (Giancarlo, 2006).

According to Boud et al. (1985), the reflective process is a complex one in which feelings and cognition are closely interrelated and interactive thereby enabling effective problem solving to take place and improving the effectiveness of learning. Bruner (1966) suggested that by having students reflect back on a difficulty, think about what occurred, and evaluate the outcomes, they might be helped to increase their conceptual understanding and long-term knowledge retention. Marzano (2007) noted that reflection is an intentional act, engaging students in questioning their own thinking to construct understanding of it. Reflective practice is a continuous process that involves the learner considering critical incidents in his or her learning or life experiences (Schön, 1983).

Research supports the successful use of reflection at both the college level (Lerch, Bilics, & Colley, 2006; Phan, 2009) and the K-12 education level (Greenwood, 2010; Pivovar, 2010). Successful instructional methods for incorporating reflective practice are

reflective journals (Chirema, 2006; Correia & Bleicher, 2008; Davis, 2003; Henderson, Napan, & Monteiro, 2004; Taylor-Haslip, 2004; Uline, Wilson, & Cordry, 2004), exit slips (Leigh, 2012), and verbal reflective discussions (Henderson et al., 2004; Jindal-Snape & Holmes, 2009; Pivovar, 2010; Tsang, 2010; Yacoubian & BouJaoude, 2010). Based on these successful studies and an analysis of the findings the researcher has a basis to develop a treatment rooted in reflective practice and investigate its impact on critical thinking. This dissertation supports research in the past related to reflection and reflective practice, but more importantly, attempts to expand on the gaps found in literature related to reflection in secondary science and critical thinking.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to investigate the effect of a treatment rooted in reflection on high school science students' critical thinking and their level of reflective thinking. This chapter provides elements of the methodology used to explore this topic which includes the descriptions of the research design; setting, participants, and sampling; and reflective practice treatment. Additionally, this chapter addresses the data collection and timeline, an overview of the instrumentation used, the description and justification of the analyses, the limitations along with internal and external threats to the study, and concludes with an ethics statement.

Research Design

The research study followed a quasi-experimental pretest/posttest design with a comparison group. The design is depicted in Table 1. Random assignment of individual students was not used; rather random assignment of intact classrooms to either the comparison or the treatment group was conducted. The three teachers who agreed to take part in the study were already assigned to classes and had agreed to participate regardless of whether each classroom had been assigned to a treatment or a control group.

Table 1

Pretest/Posttest Comparison Group Research Design

Group	Pretest	Treatment	Posttest
Experimental Group (Reflective Science Instruction)	O	X	O
Comparison Group (Traditional Science Instruction)	O		O

Setting and Sampling Procedures

A sample of convenience was drawn from a population of approximately 500 high school science students located in a small, suburban school district located in southeastern New York State. The student body was approximately 96% Caucasian, 2% Hispanic or Latino/Latina, 1% African American, and 1% Asian or Native American. Demographically, the socio-economic background of the community members is middle to upper-class with a median home income of \$147,000. Only 2% of students were eligible for free or reduced lunch and 98% of students were English proficient.

A target sample of 200 participating students was originally sought from intact groups in grades 9 through 12. Potential students from this target sample were enrolled in earth science, biology, chemistry, or physics. Table 2 displays the student population from which the sample was drawn. The numbers in each under the subject indicate the number of potential students in each class, while the parenthesis indicates the number of sections, or classes, that the students could be drawn from.

Although such a large population of students was available, only three teachers consented to participate in the study, which narrowed the available sample to 122 students, from 9th through 12th grade science classes. Participating teachers and their classes were not able to be randomly selected from a range of high school science subjects and from the Regents, Honors, and advanced placement levels due to the small return of consent forms and the logistics of comparable sample sizes as seen in Table 3.

Table 2

Science Student Population for Target Sample by Grade, Course Level, and Subject

Grade	Level	Earth Science (SE) ^a	Biology	Chemistry	Physics	Forensics
9	Regents ^b	11 (2)				
	Honors ^c		52 (2)			
10	Regents		47 (3)			
	Honors			37 (2)		
11	Regents			46 (2)		23 (1)
	AP ^d		32 (2)			
12	Regents				72 (3)	
	AP				11 (1)	

Note. The student population represents the total student enrollment from which potential classes could be randomly assigned to treatment or comparison groups. ^aThe Earth Science students would be drawn from a special education section (SE). ^bRegents level courses are courses at a non-honors level. ^cHonors level courses are courses for advanced or accelerated track students. ^dAP courses are Advanced Placement courses where students may earn college credit for a course completed in high school.

Table 3

Research Sample of Science Students by Grade, Course Level, and Subject

		Earth Science (SE) ^a	Biology	Physics
Grade	Level			
9	Regents	11 ^b		
	Honors		39 ^b	
10	Honors		4 ^b	
11	Regents			9 ^c
12	Regents			50 ^c

Note. Consent was obtained from only three teachers to participate in the study which narrowed the available sample to 122 students, from 9th through 12th grade science classes.

^aThe Earth Science students would be drawn from a special education section (SE).

^bStudents assigned to the treatment group ($n = 59$), ^c Students assigned to the comparison group ($n = 54$).

The treatment group ($n = 59$) consisted of heterogeneous students' enrolled in general level physics and was comprised of nine juniors (11th grade students) and 50 seniors (12th grade students). The comparison group ($n = 54$) consisted of a heterogeneous mix of students in honors biology and special education earth science and were comprised of four sophomores (10th grade students) and 50 freshman (9th grade students).

At the start of the study, the groups were as equivalent as possible, with the exception of grade level, because each intact class from both the treatment and comparison groups were balanced with respect to number of participants, gender, and academic ability. There was no known difference between groups in terms of their level of reflective thinking as prior research does not exist that indicates that students at the 11th and 12th grade level are already higher reflective thinkers and that students at the 9th and 10th grade level are lower reflective

thinkers. Therefore, the RTQ, a measure of the level of reflective thinking, which was administered as part of the pre-test, was scored immediately and was analyzed for a significant difference between the groups. No significant difference was found between the groups for the subscales Habitual Action, Reflection, and Critical Reflection. The subscale of Understanding had a significant difference ($p < .000$) between the comparison group (9th and 10th graders) who scored higher ($M = 4.2$) than the members of the treatment group (11th and 12th graders, $M = 3.3$). The mean scores were subsequently used as a covariate for the posttest statistical analysis and are discussed further in Chapter 4.

Data Collection and Timeline

In November of 2012, prior to the start of this investigation, written consent letters were received from the district superintendent (Appendix A), and the building principal (Appendix B). Once permission was obtained for the study to be conducted at the school consent was obtained from the participating teachers, (Appendix C). In mid-December 2012, the researcher visited all potential science classes to explain the study and consent letters were sent home with students so that signatures could be obtained from the parents (Appendix D). Students were informed that their participation was voluntary and were assured that all results would be confidential and participation or non-participation in the study would not impact their science grade. Students provided their assent on a separate form (Appendix E).

At the close of January 2013, three teachers who consented to participate in the study received one hour of professional development administered by the researcher on the administration of the pre and posttests. All participating teachers were trained together to ensure instruction on administration was consistent. The participating teacher of the

treatment group received additional training on how to effectively incorporate the reflection element in his or her instruction. The training included an overview of implementing the treatment for 16 weeks, the lesson on reflection and reflective writing that students subsequently participated in, and the relevant incorporation of verbal prompts, exit slips, and reflective journal entries.

Participating students in both the treatment and the comparison groups were administered the CM3 (pretest and posttest) and the RTQ (pretest and posttest) for which data were used for the purposes of assessing the effect of reflection on critical thinking and reflective thinking, respectively. During the week of January 22, 2013, the pretests were administered to the treatment and the comparison groups. The treatment group received their opening lesson on reflection three days after their pretest. Immediately following the lesson, their science instruction was imbedded with reflective activities from January 28, 2013 until May 17, 2013. The comparison group received traditional science instruction during this time. During the week of May 20, 2013 the posttests were administered to both groups.

The duration of the treatment for the participating group was 16 weeks. This length of the study was based on the high school students' schedule and recommendations from the review of the literature. Experimental, quasi-experimental, and qualitative action research studies at the undergraduate and graduate level on the use of reflection have taken place during a semester course, approximately 16 weeks (Correia & Bleicher, 2008; Henderson, Napan, & Monteiro, 2004; Lerch, Bilics, & Colley, 2006; Phan, 2007, 2009; Taylor-Hislop, 2009; Uline, Wilson, & Cordry, 2004). Prior research studies at the K-12 education level have varied from six weeks in duration (Pivovar, 2010), to 12 weeks, (Valkanova & Watts, 2007), 16 weeks, (Fraker, 1994; Davis, 1996, 2003) and to a full 20 weeks (Ben-Chaim, Ron,

& Zoller, 2000; Greenwood, 2010). Therefore, this present study was designed to take place for an average of the recommended length of time.

Description of Treatment

The treatment began with participating students receiving a 40-minute (one class period) lesson on reflection, what it means to reflect, and how to compose a reflective writing piece (Appendix F). Examples of reflective writing pieces were exhibited, reflective prompts were introduced (Appendix G), guidelines of levels of reflective writing were provided for the journal entries (Appendix H), exit slips were discussed (Appendix I) and a model of a verbal class reflection was conducted at the conclusion of the study.

The reflective instructional treatment was three-fold. Students were required to reflect on a learning activity at least once per week in a reflective journal, to complete exit slips at least two times per week, and finally to participate in verbal class reflection at least two times per week. In all cases reflection prompts were provided (Appendices G, I). The design of the treatment and the selection of methods in which to reflect were based on the most effective strategies gleaned from the review of the literature and were intended to provide participants with a form of saturation in the construct of reflection. Reflective journals were highly effective in promoting reflection and in monitoring the presence or absence of reflection in learning (Boud et al., 1985; Boud, 2001; Chirema, 2007; Henderson, Napan, & Monteiro, 2004; Taylor-Haslip, 2009; Uline, Wilson, & Cordry, 2004). Exit slips were shown to help students enhance their meta-cognitive skills, their reflection on what they have learned, and how they expressed what or how they were thinking about new information (Bafile, 2004; Buehl, 2003; Fisher & Frey, 2004; Leigh, 2012). Verbal reflections that used dialogue to facilitate cycles of reflection and action were found to be a

positive and summative means of reflection (Henderson, Napan, & Monteiro, 2004; Jindal-Snape & Holmes, 2009; Pivovar, 2010; Tsang, 2011; Yacoubian & BouJaoude, 2010).

The treatment was designed so that students would be reflecting, in an effective way, on a daily basis. The reflective journal entry was assigned once a week, the exit slips on two days out of the week when the journal entry was not assigned, and the verbal class reflections would take place on the remaining two days where no other form of written reflection would be taking place.

Reflective Journals

The reflective journal writing required all students, as part of the normal educational process, to select a prior learning activity from the week and compose a written reflection on that activity. Reflective journal writing took approximately 15 to 20 minutes of class time and was conducted on a day that students had a double lab block of time, (80 minutes of class versus a normal 40 minutes). The lesson on reflection that students participated in provided guidelines and examples of how to write a reflective piece. Students were provided with reflection prompts (Appendix G) to guide their writing. The selection of the prompts for the writing was left to the discretion of the participating teacher based on the learning experiences the students participated in during the week. Copies of the written reflections, composed in journals, were kept to examine how students were progressing and to provide evidence that the teacher in the treatment group was using the reflection strategy. The researcher collected the reflective journals weekly to provide feedback on students' writing using a guideline of levels ranging from basic to exemplary (Appendix H). Opportunities for peer assessment and feedback on reflective writings were offered to the students on four occasions spaced periodically throughout the 16-week period the study was taking place.

Peer assessment and feedback gave students the opportunities to share their reflections with a partner, and have that partner assess the level of reflective writing using the guideline to offer constructive feedback. Analysis of peer assessment were not include within the scope of the research, but was comprised within the treatment as an opportunity for students to be motivated by the work of others and to grow in their appreciation of value of reflective writing.

Exit Slips

Students were provided with an exit slip containing a brief reflection prompt approximately twice per week, as a form of immediate reflection on a learning activity (Appendix I). The selection of the exit slip prompt was left to the discretion of the participating teacher and was selected based on the format and level of the lesson for that day. Exit slips assigned at or around the commencement of class took students approximately five minutes to complete. Copies of the students' exit slips were kept by the researcher to examine how students were progressing and provide evidence that the teacher in the treatment group was using the reflection strategy.

Verbal Reflections

Approximately, twice per week, the participating teacher in the treatment group initiated informal verbal reflections in class with the opportunity for students to share their thoughts. Verbal reflections completed at or around the commencement of class took students approximately five minutes to conduct. Six documented researcher observations of classes ensured that the verbal class reflections were taking place. Prompts for the verbal class reflections and discussion were reviewed with the participating teacher during the pre-treatment training and were the same prompts used on the exit slips.

Monitoring the Treatment

The researcher collected, copied and provided feedback on the reflective journal entries, as well as collected and copied the exit slips. Reflective journal entries and exit slips were counted as a proportional piece of a student's homework grade (10%). All students, regardless of participation status in the study, completed the reflective journal entries and exit slips as part of the regular course curriculum. Due to several days of weather-related school cancellations, school sponsored activities taking place during science class time, and spring break, the approximate number of journal entries and exit slips completed by students was lower than initially designed. Students in the treatment group completed 12 journal entries and 25 exit slips during the course of the 16-week study (see Table A in Appendix J). It was expected that they would complete 16 journal entries and 32 exit slips. The researcher met with the participating teacher of the treatment group at a minimum of one time per week to discuss the treatment and its progress. As stated earlier, the researcher conducted six classroom observations during the 16-week period of the study to ensure that verbal class reflections and other components of the treatment were being implemented. In addition, the researcher met with the participating teacher of the comparison group on three occasions, and conducted four observations of the class to ensure that reflective activities were not happening in the class.

Instrumentation

Data for this study were collected using two instruments: the *California Measure of Mental Motivation* (CM3) (Giancarlo, 2010) and the *Reflective Thinking Questionnaire* (RTQ) (Kember *et al.*, 2000). Reflective journals, exit slips, and verbal discussion observations were conducted to monitor the integrity of the research. These treatment

elements were not used as instruments for data collection, nor to inform the outcomes for the present study.

California Measure of Mental Motivation (CM3)

The CM3, administered as part of the pretest/posttest design, is a 72-item Likert type scale instrument used to measure a student's motivation toward problem solving and learning, as well as assess a student's disposition towards critical thinking (Giancarlo, 2006). The disposition domains measured by the CM3 are not linked with any particular curricular area, rather they are designed to measure the degree to which a student is cognitively engaged and mentally motivated toward intellectual activities that involve reasoning. The CM3 targets five main dispositional aspects of critical thinking: mental focus, learning orientation, creative problem solving, cognitive integrity, and scholarly rigor (Giancarlo, 2006). The responses selected by students are arranged in a 4-point response format: strongly agree, agree, disagree and strongly disagree. The approximate time to complete the CM3 is 20 minutes.

The Mental Focus Scale. Mental Focus is the discipline of being diligent, systematic, task-oriented, organized, and clear-headed. When a student is engaged in a mental activity, he or she tends to be focused, attentive, and persistent. A student lacking mental focus shows a compromised ability to regulate his or her attention and a tendency toward disorganization and procrastination (Giancarlo, 2006).

The Learning Orientation Scale. The Learning Orientation scale measures the tendency of a student to seek to increase his or her knowledge and skills, to value the learning process as a means to accomplish mastery over a task, to be interested in challenging activities, and toward using research as a personal strategy when problem solving. A student

with high learning orientation has a general inquisitiveness that guides this or her interests and activities. A student with little to no learning orientation tends to have a narrow set of interests he or she is willing to explore and may even avoid opportunities to learn and understand (Giancarlo, 2006).

The Creative Problem Solving Scale. Creative Problem Solving is the inclination to approach problem solving with innovative or original ideas and solutions. A student with strong creative problem solving skills tends to be intellectually curious, creative, to prefer challenging, complicated, and novel activities, and to be imaginative, ingenious, and artistic. A low score reflects the absence of feelings of personal imaginativeness or originality. Students with low scores tend to avoid challenging activities (Giancarlo, 2006).

The Cognitive Integrity Scale. Cognitive Integrity is the habit of interacting with differing viewpoints for the sake of learning the truth or reaching the best decision. It is the tendency of a student to express strong intellectual curiosity and value fair-mindedness and sound reasoning. A student with high cognitive integrity is comfortable with challenge and complexity, and enjoys interacting with others of varying viewpoints in the search for truth or the best decision. A student with lower cognitive integrity expresses a viewpoint that is best characterized as cognitive resistance, and is often characterized as hasty, indecisive, uncomfortable with challenge and change, and is likely to be anxious and close-minded (Giancarlo, 2006).

The Scholarly Rigor Scale. Scholarly Rigor is the disposition to work hard to interpret and achieve a deeper understanding of complex or abstract material. A student with elevated scholarly rigor exhibits a strong positive disposition toward detailed learning and is

unlikely to be deterred by the need to read a difficult text or to analyze complicated situations or problems. By contrast, a student lacking scholarly rigor would try to avoid or procrastinate if assigned difficult, complicated, or detailed scholarly work (Giancarlo, 2006).

Validity and Reliability. The CM3 has established reliability and validity. Three separate studies support the reliability and validity of the CM3. Two of the studies were conducted in Northern California using both male and female high school students from diverse backgrounds (Giancarlo, 2006). The third study was performed in the mid-western United States and involved predominantly Caucasian females (Giancarlo, 2006). Internal consistency of scores obtained by the CM3 was evaluated using Cronbach's alpha coefficient. The reliability estimate for Learning Orientation ranged from .79 - .83 across the various studies. Creative Problem Solving produced an alpha coefficient ranging from .70 - .77, Mental Focus ranged from .79 - .83, and Cognitive Integrity ranged from .53 - .63.

The researchers have established validity. All four scales of the CM3 resulted in statistically significant positive correlations ($p < .01$) when correlated with various measures of student motivation, behavior, and achievement (Giancarlo, 2006).

The Reflective Thinking Questionnaire (RTQ)

The RTQ, administered as part of the pretest/posttest design, is a 16-item Likert type scale instrument used to measure the extent to which students engage in reflective thinking (Kember et al., 2000). The instrument is suitable for high school students, undergraduate, and graduate level college students in various academic courses. The RTQ measures the level of reflective thinking using four subscales: habitual action, understanding, reflection, and critical reflection. Each subscale consists of four contributing items and is not linked with any particular curricular area. The responses selected by students use a Likert-style of

five choices: strongly agree, agree, undecided, disagree, and strongly disagree. Strongly agree is scored as a five, somewhat agree is scored as a four, undecided is scored as a three, somewhat disagree is scored as a two, and strongly disagree which is scored as a one. The approximate time to complete the RTQ is five minutes.

Habitual Action Scale. Habitual Action refers to activities that are performed automatically or with little conscious thought. Schön (1983) called this type of behavior knowing-in-action. A student who completes activities without thinking about what he or she is doing is employing a habitual response to their activities (Kember et al., 2000).

Understanding Scale. This scale focuses on a narrow construct of comprehension and emphasizes the academic-type of learning in which a student might reach an understanding of a concept without reflecting upon its significance in personal or practical situations. High scores on this scale indicate that a student agrees that the course requires them to understand content taught by the instructor. Low scores on this scale indicate that a student does not agree that it is necessary to understand the subject matter of the course in order to be successful (Kember et al., 2000).

Reflection Scale. This scale is based on the definitions of reflection by Dewey (1933), Mezirow (1991), and Boud *et al.*, (1985) and is of particular relevance to professional practice in that it views experience as the touchstone for reflection (Kember et al., 2000, p. 385). “Reflection in the context of learning is a generic term for those intellectual and affective activities in which individuals engage to explore their experiences in order to lead to new understandings and appreciations” (Boud *et al.*, 1985, p. 19) . High scores on this scale indicate that a student thinks about what he or she is doing, considers alternative ways, and looks for areas to improve on for the future. A student with a lower score on this scale is

not inclined to question the way things are done or to try and think of alternative ways to accomplish tasks (Kember et al., 2000).

Critical Reflection Scale. This scale measures a profound level of reflection that requires an examination of all possibilities before reaching a conclusion. To undergo a perspective transformation it is necessary to recognize that many of our actions are governed by a set of beliefs and values that have been almost unconsciously assimilated from the particular environment. Critical reflection then requires a decisive review of presuppositions from conscious and unconscious prior learning and their consequences. Conventional wisdom and ingrained assumptions are hard to change, in part because they become so deeply embedded that we become unaware that they are assumptions or that they even exist. Critical reflection is unlikely to be observed frequently, as understanding or reflective thinking, since it needs a significant change in perspective. High scores on this scale indicate that students challenge their firmly held ideas, adjust their normal ways of doing things, and change the way they view themselves (Kember *et al.*, 2000).

Validity and Reliability. The RTQ has established reliability and validity by means of four separate studies using the RTQ (Kember et al., 2000). The studies were conducted at a health science facility in Hong Kong using both male and female undergraduate and graduate students ($n = 303$) enrolled in occupational therapy, physiographic, radiographic, and nursing courses. Internal consistency of scores obtained by the RTQ was evaluated using Cronbach's alpha coefficient. The reliability estimate and alpha values for each of the subscales were: Habitual Action, .621; Understanding, .757; Reflection, .631; and Critical Reflection, .675.

The researchers established validity for the scales as they were derived from well-established literature on the nature of reflective thinking. The relative values of mean scores for the four scales were in line with predictions about the likelihood of that type of thinking being present in the samples. Additionally, all four scales of the RTQ resulted in statistically significant positive correlations ($p < .05$) when each item was tested to ensure that it was measuring that scale and not contributing to others (Kember et al., 2000).

Type of Data and Analysis

Data collected were interval-level and quantitative in nature in the form of subscale means using the *California Measure of Mental Motivation* (CM3) (Giancarlo, 2010) and the *Reflective Thinking Questionnaire* (RTQ) (Kember et al., 2000). Instrument data were used for the purposes of assessing the effect of reflection on learning experiences in science on student's critical thinking and level of reflective thinking. Data were analyzed using SPSS statistical software (2006).

For the first research question, five dependent variables, the five scales of the CM3 instrument, were measured before and after implementing the treatment in this study. A multivariate analysis of variance (MANOVA) was used to determine if there were differences in students' posttest critical thinking on the CM3 between those who participated in reflection on science learning experiences and those who did not.

For the second research question, the four scales of the RTQ instrument served as dependent variables and were measured before and after implementing the treatment in this study. A multivariate analysis of variance (MANOVA) was used to determine if there were differences in students' level of reflective thinking on the posttest RTQ scores between those who participated in reflection on science learning experiences and those who did not.

For the third research question, three hierarchical multiple linear regression analyses were used to determine if the variables of reflective thinking (Reflection and Critical Reflection) predicted the variables of critical thinking (Mental Focus, Cognitive Integrity, and Scholarly Rigor). A Bonferroni adjustment was employed for the first two research questions since the same data were used in research question three. A Bonferroni correction suggests a more stringent p value than typically considered acceptable in behavioral science studies ($p < .05$). The Bonferroni correction divides the accepted significance value by the number of statistical analyses undertaken (Meyers, Gamst, & Guarino, 2006). The alpha value was set at $p = .025$, by dividing the initial alpha level of .05 by the number of times a specific set of data were used (.05/2). The data for research question one was derived from the five subscales of the CM3. Three of these subscales, Mental Focus, Cognitive Integrity, and Scholarly Rigor, were used again in research question three. The data for research question two were derived from the four subscales of the RTQ. Two of these subscales, Reflection and Critical Reflection, were used again in research question three. Research question three did not employ a Bonferroni correction as it was considered exploratory in nature and its results were analyzed for that purpose.

Statement of Ethics and Confidentiality

Permission to participate in this research was sought from the school district's superintendent, principal, and all participating teachers. Parent permission and student consent were secured before the study. This research was approved by the Institutional Review Board of Western Connecticut State University (protocol number 1213-59). No names of subjects, schools or districts were used to report the findings of the study. Student confidentiality was maintained. Data were coded numerically and reported in group format. All data were stored in a locked filing cabinet in the researcher's office and will be

maintained there until the findings are published; these data will be accessible only to other researchers for whom the data will prove useful in further comparative analyses and who are associated with Western Connecticut State University's Doctor of Education in Instructional Leadership Program.

CHAPTER FOUR: ANALYSIS OF THE FINDINGS AND EXPLANATION OF THE DATA

The purpose of this study was to test the effects a reflective practice implementation on the critical and reflective thinking of high school science students. The specific research questions and hypotheses addressed were:

1. Is there a significant difference in critical thinking as measured by the mean scores on each of the *California Measure of Mental Motivation (CM3)* subscales (Mental Focus, Learning Orientation, Creative Problem Solving, Cognitive Integrity, and Scholarly Rigor) of high school science students who participate in a reflection program on classroom learning experiences and those who do not?

Non-directional hypothesis: There will be significant difference in critical thinking as measured by the mean scores on each of the CM3 subscales (Mental Focus, Learning Orientation, Creative Problem Solving, Cognitive Integrity, and Scholarly Rigor) of high school science students who participate in a reflection program on classroom learning experiences and those who do not.

2. Is there a significant difference in the level of reflective thinking as measured by the mean scores on each of the *Reflective Thinking Questionnaire (RTQ)* subscales (Habitual Action, Understanding, Reflection, and Critical Reflection) in high school science students who participate in a reflection program on classroom learning experiences and those who do not?

Non-directional hypotheses: There will be significant difference in level of reflective thinking as measured by each of the RTQ subscales (Habitual Action, Understanding, Reflection, and Critical Reflection) of high school science

students who participate in a reflection program on classroom learning experiences and those who do not.

3. To what extent and in what manner do each one of the variables reflection and critical reflection, as measured by the RTQ, significantly predict the critical thinking variables of Mental Focus, Cognitive Integrity, and Scholarly Rigor, as measured by the CM3, after accounting for the variance in program participation?
Non-directional hypothesis: The variables of Reflection and Critical Reflection, as measured by the RTQ, will either together or individually, significantly predict the variables Mental Focus, Cognitive Integrity, and Scholarly Rigor, as measured by the CM3, after accounting for the variance in program participation.

The results are presented in the following sections: types of data, screening of data, analysis of the findings of research question one, analysis of the findings of research question two, analysis of the findings of research question three, and chapter summary.

Types of Data

The data analysis incorporated the student results from the *California Measure of Mental Motivation (CM3)* and *The Reflective Thinking Questionnaire (RTQ)*. The CM3 produced the following five scales: Mental Focus, Learning Orientation, Creative Problem Solving, Cognitive Integrity, and Scholarly Rigor. The RTQ produced the following four scales: Habitual Action, Understanding, Reflection, and Critical Reflection. Interval level data were collected and analyzed for each of these instruments for the pretests and the posttests and represent the dependent variables. The independent variable for this study was program type: science instruction with imbedded reflective practice (treatment group) and traditional science instruction (comparison group).

Data Screening Process

Visual inspection. Once the data from the CM3 and the RTQ were collected, a confirmation procedure was utilized in order to check the numerical codes for all values (Meyers, Gamst, & Guarino, 2006). Data screening continued with the completion of a visual inspection. The data were entered into a statistics software program (SSPS, 2006). During the visual inspection, the researcher found that there were no missing values, and that all values were numerical and of the appropriate range of accepted values.

Multivariate outliers. After the data were visually inspected and screened, extreme values tests were run to detect outliers (Meyers, et al., 2006). Based on the recommendation of Hair, Anderson, Tatham, and Black (1998), outliers were removed for the pretest and posttest data, as these values were greater than the two standard deviations from the mean.

The values that were removed from the data were case numbers 63, 64, 76, 103, 111, and 113 from the comparison group. Case numbers 2, 18, 36, and 43 were removed from the treatment group. As a result of these procedures, the total sample size went from 113 (reflective practice treatment group $n = 59$; comparison group $n = 54$) to 103 (reflective practice treatment group $n = 55$; comparison group $n = 48$).

Descriptive Statistics of Pretest Data

After the removal of the outliers, descriptive statistics were analyzed for the pretest data. Results are presented in Table 4, which describe the mean, standard deviation, skewness, and kurtosis of each dependent variable across both treatment and comparison groups.

Table 4

Descriptive Statistics for Pretests of Independent Variables with Respect to each Dependent Variable from the CM3 and RTQ

Dependent Variable	Research	Standard			
	Group	Mean	Deviation	Skewness	Kurtosis
Mental Focus	Treatment	27.41	7.20	.390	-.244
	Comparison	27.04	6.23	-.085	-.621
Creative Problem Solving	Treatment	28.69	5.74	-.028	.198
	Comparison	27.60	8.36	.100	-.643
Learning Orientation	Treatment	30.18	6.97	.018	-.190
	Comparison	29.04	9.80	.033	-.554
Cognitive Inquiry	Treatment	30.78	8.61	-.446	-.335
	Comparison	29.93	8.29	-.263	-.703
Scholarly Rigor	Treatment	26.25	4.35	.285	-.279
	Comparison	25.58	7.12	-.460	-.003
Habitual Action	Treatment	3.35	0678	-.233	-.125
	Comparison	3.22	.729	.161	-1.00
Understanding	Treatment	3.31	1.06	-.417	-.968
	Comparison	4.36	.513	-.716	-.242
Reflection	Treatment	3.34	.686	-.466	-.176
	Comparison	3.43	.888	-.353	-.208

(continued)

Table 4

Descriptive Statistics for Pretests of Independent Variables with Respect to each Dependent Variable from the CM3 and RTQ

Dependent Variable	Research	Standard			
	Group	Mean	Deviation	Skewness	Kurtosis
Critical Reflection	Treatment	2.46	.895	.096	-1.00
	Comparison	2.64	.736	-.274	-.309

Note. Treatment group ($n = 55$) and Comparison group ($n = 48$).

Individual t -tests were conducted to examine initial differences between groups across all dependent variables with respect to the pretest data. For all pretest scores, there were no significant differences between the treatment group (reflective practice) and the comparison group for any subscale of the CM3 (Mental Focus, Learning Orientation, Creative Problem Solving, Cognitive Integrity, and Scholarly Rigor) or the RTQ (Habitual Action, Reflection, and Critical Reflection). However, the RTQ subscale of Understanding had a statistically significant difference ($p < .000$) between groups. Students in the comparison group (9th and 10th graders) scored higher ($M = 4.37$) than the members of the treatment group (11th and 12th graders, $M = 3.33$). Due to this result, the subscale of Understanding was used as a covariate for the posttest statistical analysis (Meyers, et al., 2006).

Research Question One Posttest Data Analysis

Assumptions for Research Question One

After the pretest data had been cleaned and outliers were removed, assumptions for posttest data concerning research question one were checked. Following the recommendation of Meyers, et al. (2006), the assumptions of normality, linearity, and homoscedasticity were investigated before moving forward with the posttest data analysis.

Normality. The shape and distribution of the variables should relate to a normal distribution, or resemble a bell shaped curve. For this assumption, the skewness and kurtosis for each dependent variable were assessed and are displayed in Table 5. Since all values were not within the +1.0 to -1.0 ranges, the data were not acceptable for the normality assumption (Meyers, et al., 2006). The comparison group exhibited a kurtosis of exactly -1.0 for the dependent variable of Learning Orientation. Due to this result a Kolmogorov-Smirnov test was conducted to check if normality was violated in this case. The Kolmogorov-Smirnov test (Meyers, et al., 2006) compares the cumulative frequency distributions of the two groups. According to Stevens (2002), this test is the most powerful at detecting departures from normality. Statistical significance with this measure is set at a very stringent alpha level ($p < .001$). Table 6 presents the results of hypothesis normality test, the Kolmogorov-Smirnov, and shows that this assumption has not been violated.

Table 5

Descriptive Statistics for CM3 Posttest of Independent Variables with Respect to Each Dependent Variable

CM3 Dependent Variable	Research Group	Mean	Standard Deviation	Skewness	Kurtosis
Mental Focus	Treatment	26.76	7.27	.600	-.354
	Comparison	27.35	8.31	-.017	-.603
Creative Problem Solving	Treatment	29.80	6.52	-.212	.668
	Comparison	31.47	8.07	.198	-.514
Learning Orientation	Treatment	29.85	6.78	.274	-.278
	Comparison	32.18	8.12	.109	-1.00
Cognitive Inquiry	Treatment	31.05	8.04	.064	-.120
	Comparison	33.31	7.63	-.715	.507
Scholarly Rigor	Treatment	28.09	4.92	.220	-.372
	Comparison	27.16	6.80	-.041	-.832

Note. Treatment group ($n = 55$), Comparison group ($n = 48$)

Table 6

Tests of Normality for CM3 Posttests with Respect to Each Dependent Variable

CM3 Dependent Variables	Group	Kolmogorov-Smirnov	
		Statistic	Sig.
Mental Focus	Treatment	.152	.003
	Comparison	.081	.200
Creative Problem Solving	Treatment	.088	.200
	Comparison	.064	.200
Learning Orientation	Treatment	.097	.200
	Comparison	.096	.200
Cognitive Integrity	Treatment	.079	.200
	Comparison	.108	.200
Scholarly Rigor	Treatment	.083	.200
	Comparison	.087	.200

Note. Treatment group $n = 55$, Comparison group $n = 48$.

Linearity. Linearity means that the amount of change between scores on two variables are constant for the entire range of scores for the variables. By checking correlations between variables (Pearson $r > .05$) and by visually inspecting scatter plot graphs and histograms across all variables, no curvilinear relationships were observed among any of the dependent variables (Meyers, et al., 2006). Therefore, this assumption was not violated.

Homoscedasticity. Since more than one dependent variable was used in this statistical analysis a Box's Test of Equality of Covariance Matrices tests were conducted to test for homoscedasticity (Meyers, et al., 2006). The assumption of homoscedasticity

suggests quantitative dependent variables have equal levels of variability across a range of independent variables. The Box's Test of Equality of Covariance Matrices was significant (*Box's M* = 48.404 , $p < .000$), as seen in Table 7, demonstrating that the observed covariance matrices of the dependent variables were not equal across groups and that homoscedasticity was violated.

Table 7

Box's Test of Equality of Covariance Matrices

<i>Box's M</i>	48.404
<i>F</i>	3.054
<i>Df1</i>	15
<i>Df2</i>	39437.535
<i>p</i>	.000

Random elimination of data. Since the data were in violation of homoscedasticity or equality of variance, the researcher followed the standard practice to equalize frequencies. The groups would be equalized based on size using a random number generator to select cases in the treatment group ($n = 55$) that would be eliminated to reduce the size of the treatment group to be equal with the comparison group ($n = 48$). Using a random number table the researcher eliminated seven cases from the treatment data for the CM3. The eliminated cases were 01, 09, 14, 21, 39, 42 and 50. This reduced the size of the treatment group to be equal with the comparison group ($n = 48$).

Descriptive statistics and assumptions were checked for the new data source. Table 8 displays the new means, standard deviations, skewness, and kurtosis. All variables were

within the accepted range of absolute 1.0 with the exception of the comparison group which exhibited a slight kurtosis (-1.00) for the subscale of Learning Orientation.

Table 8

Descriptive Statistics for Posttests of Independent Variables with Respect to Each Dependent Variable

CM3 Dependent Variable	Research Group	Mean	Standard Deviation	Skewness	Kurtosis
Mental Focus	Treatment	27.04	7.52	.531	-.476
	Comparison	27.35	8.31	-.017	-.603
Creative Problem Solving	Treatment	30.08	6.06	.178	.271
	Comparison	31.47	8.07	.198	-.514
Learning Orientation	Treatment	30.16	6.99	.211	-.352
	Comparison	32.18	8.12	.109	-1.00
Cognitive Inquiry	Treatment	30.89	7.87	-.131	-.342
	Comparison	33.31	7.63	-.715	.507
Scholarly Rigor	Treatment	28.43	5.02	.121	-.397
	Comparison	27.16	6.799	-.041	-.832

Note. Treatment ($n = 48$), Comparison ($n = 48$).

The Kolmogorov-Smirnov test of normality was not conducted as both groups were now smaller than $n = 50$, however, a Shapiro-Wilk normality test was conducted instead.

Table 9 displays the results of the Shapiro-Wilk and shows that the data were not in violation of normality as $p > .05$ (Meyers, et al., 2006).

Table 9

Tests of Normality for Independent Variable Data with Respect to Each Dependent Variable

CM3 Dependent Variables	Research Group	Shapiro-Wilk	
		Statistic	Sig
Mental Focus	Treatment	.954	.056
	Comparison	.978	.508
Creative Problem Solving	Treatment	.980	.568
	Comparison	.982	.658
Learning Orientation	Treatment	.975	.402
	Comparison	.962	.126
Cognitive Integrity	Treatment	.985	.780
	Comparison	.958	.086
Scholarly Rigor	Treatment	.977	.477
	Comparison	.966	.184

Note. Treatment ($n = 48$), Comparison ($n = 48$).

By checking correlations between variables (Pearson $r > .05$) and by visually inspecting scatter plot graphs and histograms across all variables, no curvilinear relationships were observed among any of the dependent variables (Meyers, Gamst, & Guarino, 2006) and this assumption was not violated.

Homoscedasticity tests were conducted on the new data, Box’s Test of Equality of Covariance Matrices and Bartlett’s Sphericity (Meyers, et al., 2006). The Box’s Test of Equality of Covariance Matrices was still significant ($Box's M = 48.300$, $p < .000$), as seen in Table 10, demonstrating that the observed covariance matrices of the dependent variables were not equal across groups and that homogeneity of variance was still violated for the new data. However, “violation of this homogeneity of covariance matrices assumption when sample sizes are fairly equal produces minor consequences” (Meyers, et al., 2006, p. 378). Based on this postulation, the researcher continued with the statistical analysis.

Table 10

Box’s Test of Equality of Covariance Matrices for New CM3 Data

<i>Box’s M</i>	48.300
<i>F</i>	3.036
<i>df1</i>	15
<i>df2</i>	35576.526
<i>p</i>	.000

A significant ($p < .05$) Bartlett’s Test of Sphericity indicates that there is sufficient correlation between the set of dependent variables to proceed with the analysis. A multivariate analysis of variance is most efficient with a high or moderate correlation (.6) among the dependent variables (Tabachnik & Fidell, 2001b). Dependent variables that have very high correlations (.8 or .9) would be deemed redundant and a MANOVA would be considered counterproductive (Meyers, et al., 2006). Table 11 below shows the significant

results of the test of intercorrelation of dependent variables ($p < .000$) and Table 12 displays the moderate correlations ($< .8$) between the dependent variables.

Table 11

Bartlett's Test of Sphericity on New CM3 Data

Likelihood Ratio	.000
Approximate <i>Chi-Square</i>	185.588
<i>df</i>	14
Significance	.000

Table 12

Correlation Matrix of the Dependent Variables for New CM3 Data

	1.	2.	3.	4.
1. Mental Focus				
2. Creative Problem Solving	.554			
3. Learning Orientation	.436	.565		
4. Cognitive Integrity	.378	.347	.401	
5. Scholarly Rigor	.567	.532	.684	.509

Analysis of Data for Research Question One

An analysis was conducted on the data to test the effect of a reflective practice treatment on high school science students' critical thinking. A multivariate analysis of variance (MANOVA) was conducted using five dependent variables included in research question one, the five subscales of the CM3. The independent variable was program type

with two levels. Students participating in the reflective practice instruction were part of the treatment group. Students participating in the traditional science instruction were part of the comparison group.

Effects of reflective practice on the dependent variables. A Pillai's Trace (Meyers, et al., 2006) was performed on the five dependent variables. A Pillai's criterion is recommended whenever heterogeneity persists as seen with a significant Box's M ($p < .001$) (Tabachnik & Fidell, 2011b). There were no statistically significant differences, $F(5, 90) = 2.67, p = .027$, between the means of the treatment and comparison groups with a Bonferroni correction setting the alpha at $p < .025$. A Bonferroni correction that lowers the alpha level protects against inflated Type I errors due to the use of multiple univariate tests. The Bonferroni correction divides the accepted significance value by the number of statistical analyses undertaken (Meyers, Gamst, & Guarino, 2006). The alpha value set at $p = .025$ was determined by dividing the initial alpha level of .05 by the number of times a specific set of data were used ($.05/2$). The data for research question one were derived from the five subscales of the CM3. Three of these subscales, Mental Focus, Cognitive Integrity, and Scholarly Rigor, were used again in research question three.

Table 13 displays the outcomes from the MANOVA. Since the Pillai's Trace was not significant ($p = .027$), the non directional hypothesis was not accepted. The null hypothesis of no significant difference was accepted. Although not significant in nature, it is interesting to note that the alpha is close to the $p < .025$, and were the data assessed at the $p = .05$ level, there would be a significant difference between the groups. A Test of Between-Subject Effects was not conducted as the model did not show any significant difference.

Table 13

Multivariate Tests for Research Question One

Effect	Value	<i>F</i>	Hypothesis	Error	<i>p</i>	Partial Eta	
			<i>df</i>	<i>Df</i>		Squared	
Intercept	Pillai's Trace	.968	545.535	5.000	90.000	.000	.968
Group	Pillai's Trace	.129	2.657	5.000	90.000	.027	.129

Equal variances across groups. The Levene's Test of Error Variances checks for homogeneity of variance violations for each dependent variable. Results show a statistical significance at the $p < .05$ level for the subscales of Creative Problem Solving and Scholarly Rigor. However, equal variances were assumed across groups because even though results were significant at the $p < .05$ level, frequencies were equalized by balancing the group size. A significant Levene's does not violate equality of variance when group frequencies are equal (Meyers, et al., 2006). Table 14 displays the results of the Levene's Test.

Table 14

Levene's Test of Equality of Error Variances for Posttests on New CM3 Data

	<i>F</i>	<i>p</i>
Mental Focus	.271	.604
Creative Problem Solving	4.520	.036*
Learning Orientation	2.370	.127
Cognitive Inquiry	.136	.713
Scholarly Rigor	5.724	.019*

Note. Degrees of freedom ($df1 = 1$; $df2 = 94$), *Significant at the $p < .05$ level.

Research question one findings summary. Research question one asked, is there a significant difference in critical thinking as measured by the mean scores on the *California Measure of Mental Motivation* (CM3) subscales (Mental Focus, Learning Orientation, Creative Problem Solving, Cognitive Integrity, and Scholarly Rigor) of high school science students who participate in a reflection program on classroom learning experiences and those who do not?

The treatment group (reflective practice group) had a sample size of $n = 59$ that was reduced to $n = 48$ after outliers were dropped and group size was reduced to control for equality of variance by matching frequencies with the comparison group. The comparison group (no reflective practice) size was $n = 54$ at the start of the study but was reduced to $n = 48$ once outliers were dropped from the data. A multivariate analysis of variance (MANOVA) was applied where the five subscales of the CM3 (Mental Focus, Creative Problem Solving, Learning Orientation, Cognitive Integrity, and Scholarly Rigor) served as the multiple dependent variables. The independent variable, program type, had two levels being (a) reflective practice implemented and (b) no reflective practice implemented. A Pillai's Trace allowed for the evaluation of differences on the independent variable in the population on the dependent variables. This multivariate test revealed no statistical significance ($F(5, 90) = 2.67, p = .027$) in the participants' critical thinking dispositions after the treatment. This suggests the two groups, (a) reflective practice and (b) no reflective practice, displayed no differences in their critical thinking dispositions after the 16-week administration of the treatment (reflective practice), when measured with the CM3 as the pretest and posttest.

Research Question Two Data Analysis

Assumptions for Research Question Two

Once the outliers were removed the posttest data were adjusted and assumptions were checked for the subscales of the RTQ instrument. Following the recommendation of Meyers, Gamst, and Guarino (2006), the assumptions of normality, linearity, and homoscedasticity were investigated before moving forward with the data analysis.

Normality. The shape and distribution of the variables should relate to a normal distribution, or resemble a bell shaped curve. For this assumption, the skewness and kurtosis for each variable were assessed. Since all values were not at or within -1.0 to +1.0 ranges, the data were not acceptable for the normality assumption (Meyers, et al., 2006). Table 15 shows that kurtosis has been violated for the variables of Habitual Action (-1.15), and Understanding (-2.7) with the comparison group and for Understanding (-1.18) with the treatment group. Additionally, the variable Understanding showed a small violation in skewness (-1.37) with the comparison group.

Table 15

Descriptive Statistics for Posttests of Independent Variables with Respect to Each Dependent Variable of the RTQ

RTQ Dependent Variable	Research Group	Mean	Standard Deviation	Skewness	Kurtosis
Habitual Action	Treatment	3.43	.828	-.524	-.460
	Comparison	3.06	.927	-.168	-1.15*
Understanding	Treatment	3.04	.983	.055	-1.18*
	Comparison	4.05	.775	-1.37*	2.70*
Reflection	Treatment	3.68	.699	-.824	.722
	Comparison	3.26	.739	-.106	-.693
Critical Reflection	Treatment	2.64	.861	.205	-.407
	Comparison	2.55	.924	.446	-.434

Note. Treatment group ($n = 55$), Comparison group ($n = 48$) * Exceeds the recommended ± 1.0 indicating a violation in normality.

Due to this violation in normality, a Kolmogorov-Smirnov test was conducted to check if normality was violated in this case. The Kolmogorov-Smirnov test compares the cumulative frequency distributions of the two groups. According to Stevens (2002), these tests are the most powerful at detecting departures from normality. Statistical significance with these measures is set at a very stringent alpha level ($p < .001$). Table 16 displays the results of the Kolmogorov-Smirnov and shows that this assumption has not been violated and the researcher continued with the data analysis.

Table 16

Kolmogorov-Smirnov Test of Normality for the RTQ Independent Variables with Respect to Each Dependent Variable

RTQ Dependent Variables	Group	Kolmogorov-Smirnov		
		Statistic	<i>df</i>	Sig.
Habitual Action	Treatment	.135	55	.013
	Comparison	.125	48	.058
Understanding	Treatment	.144	55	.006
	Comparison	.179	48	.001
Reflection	Treatment	.127	55	.005
	Comparison	.111	48	.181
Critical Reflection	Treatment	.129	55	.024
	Comparison	.123	48	.069

Linearity. Linearity means that the amount of change between scores on two variables are constant for the entire range of scores for the variables. By checking correlations between variables (Pearson $r > .05$) and by visually inspecting scatter plot graphs and histograms across all variables, no curvilinear relationships were observed among any dependent variables (Meyers, et al., 2006). This assumption was not violated.

Homoscedasticity. Since more than one dependent variable was used in this statistical analysis, a Box's Test of Equality of Covariance Matrices was conducted in order to test homoscedasticity (Meyers, et al., 2006). The Box's Test of Equality of Covariance Matrices was not significant ($Box's M = 8.306, p = .634$), as seen in Table 17, demonstrating

that the observed covariance matrices of the dependent variables were equivalent across groups. The researcher proceeded with further analyses since the assumption of homoscedasticity was not violated according to Stevens (2002).

Table 17

Box's Test of Equality of Covariance Matrices

<i>Box's M</i>	8.306
<i>F</i>	.795
<i>Df1</i>	10
<i>Df2</i>	46724.190
<i>p</i>	.634

A significant ($p < .05$) Bartlett's tests of Sphericity indicates that there is sufficient correlation between the two dependent variables to proceed with the analysis. In this case the Bartlett's Test for Sphericity is at exactly $p = .05$ so the researcher accepted the results and continued with data analysis. A multivariate analysis of variance is most efficient with a high or moderate correlation (.6) among dependent variables (Tabachnik & Fidell, 2001b). Dependent variables that have very high correlations (.8 or .9) would be deemed redundant and a MANOVA would be considered counterproductive (Meyers, et al., 2006). Table 18 below shows the necessary and significant results of the test of intercorrelation of dependent variables ($p = .05$) and Table 19 displays the moderate correlations ($< .6$) between the dependent variables.

Table 18

Bartlett's Test of Sphericity

Likelihood Ratio	.000
Approximate Chi-Square	16.530
<i>df</i>	9
Significance	.05

Table 19

Correlation Matrix of the Dependent Variables for RTQ

	1.	2.	3.
1. Habitual Action			
2. Understanding	-.090		
3. Reflection	-.008	.189	
4. Critical Reflection	-.099	.185	.256

Analysis of Data for Research Question Two

A data analysis was conducted on the data to test the effect of a reflective practice treatment on high school science students' level of reflective thinking. A multivariate analysis of covariance (MANCOVA) was conducted using the four dependent variables included in research question two, the subscales Habitual Action, Understanding, Reflection, and Critical Reflection, of the RTQ. The independent variable was program type with two levels, the reflective practice treatment and the traditional instruction as comparison. A Wilks' Lambda (Meyers, et al., 2006) was performed using the four dependent variables.

There was a statistically significant difference, $F(4, 97) = 11.784, p < .001$, partial $\eta^2 = .327$, between the means of the treatment and comparison groups with a Bonferroni correction that sets the alpha set at $p < .025$. Table 20 displays the outcomes from the MANCOVA.

Table 20

Multivariate Tests for Research Question Two

Effect	Value	F	Hypothesis	Error	p	Partial Eta	
			df	Df		Squared	
Intercept	Wilks' Lambda	.301	56.183	4.000	97.000	.000	.699
Group	Wilks' Lambda	.673	11.784	4.000	97.000	.000*	.327

Note. *Significant at the $p < .025$ level.

Equal variances across groups. The Levene's Test of Error Variances checks for homogeneity of variance violations for each dependent variable. After analyzing the data, equal variances were not assumed across groups because results were not statistically significant at the $p < .05$ level for the subscales of Understanding and Reflection. Table 21 shows the values for the Levene's Test for each dependent variable.

Table 21

Levene's Test of Equality of Error Variances for RTQ Posttests

	F	p
Habitual Action	1.746	.189
Understanding	6.564	.006*
Reflection	4.173	.045*
Critical Reflection	.453	.502

Note. ($df1 = 1, df2 = 101$). *Significant at the $p < .05$ level indicating a violation in equality of variance.

Random elimination of data. Since the data were in violation of equality of variance, the researcher followed the standard practice to equalize frequencies as was done with data from research question one. The groups were based on size using a random number generator to select cases in the treatment group ($n = 55$) to reduce the size of the treatment group to be equal with the comparison group ($n = 48$). Using a random number table, the researcher eliminated seven cases from the treatment data for the CM3. Therefore, the researcher chose to use the same cases on the RTQ. The eliminated cases were 01, 09, 14, 21, 39, 42 and 50. This reduced the size of the treatment group to be equal with the comparison group ($n = 48$).

Descriptive statistics and assumptions were checked for the new data source. Table 22 displays the means, standard deviations, skewness, and kurtosis. Descriptive statistics show that the new data set is in violation of normality. The comparison group showed a violation in kurtosis on the variables of Habitual Action (-1.15) and Understanding (2.7) and a violation in skewness on the subscale of Understanding (-1.37). The treatment group showed slight kurtosis on the subscale of Understanding (-1.12). Therefore a more stringent normality test, the Shapiro-Wilk, was conducted on the new data. The Kolmogorov-Smirnov test of normality was not conducted as both groups were now smaller than $n = 50$ (Meyers, et al., 2006). Table 23 displays the Shapiro-Wilk result. The comparison group continued to show a violation in normality, according to the Shapiro-Wilk, for the subscale of Understanding ($p < .001$).

Table 22

Descriptive Statistics for New Data for RTQ Posttests of Independent Variables with Respect to Each Dependent Variable

RTQ Dependent Variable	Research Group	Mean	Standard Deviation	Skewness	Kurtosis
Habitual Action	Treatment	3.38	.869	-.389	-.722
	Comparison	3.06	.927	-.168	-1.15*
Understanding	Treatment	2.96	.973	-.003	-1.12*
	Comparison	4.05	.775	-1.37*	2.7*
Reflection	Treatment	3.70	.696	-.807	.962
	Comparison	3.26	.739	-.106	-.693
Critical Reflection	Treatment	2.67	.869	.024	-.420
	Comparison	2.55	.924	.446	-.434

**Note.* Exceeds the recommended ± 1.0 indicating a violation in normality.

Table 23

Tests of Normality for New RTQ Data

RTQ Dependent Variables	Group	Shapiro-Wilk		
		Statistic	<i>df</i>	Sig
Habitual Action	Treatment	.952	48	.050
	Comparison	.942	48	.020
Understanding	Treatment	.954	48	.056
	Comparison	.891	48	.000*
Reflection	Treatment	.939	48	.015
	Comparison	.976	48	.430
Critical Reflection	Treatment	.978	48	.491
	Comparison	.963	48	.136

Note. *Significant at the $p < .001$ level indicating a violation in normality.

Due to the significant difference between the two groups on the pretest *t*-test and the continued violations in normality for the subscale of Understanding, the researcher removed it from the multivariate analysis of covariance (MANCOVA) and from the study because it did not meet the assumptions. Given that Understanding was removed from the study, the researcher continued with a multivariate analysis of variance (MANOVA) for the remaining three subscales of the RTQ: Habitual Action, Reflection, and Critical Reflection.

After the removal of the subscale of Understanding, homoscedasticity tests were conducted on the new data, Box's Test of Equality of Covariance Matrices and Bartlett's Sphericity (Meyers, et al., 2006). The Box's Test of Equality of Covariance Matrices was not significant (*Box's M* = 2.997, $p = .822$), as seen in Table 24, demonstrating that the

observed covariance matrices of the dependent variables were equal across groups and that homoscedasticity was not violated for the new data.

Table 24

Box's Test of Equality of Covariance Matrices for New RTQ Data

<i>Box's M</i>	2.997
<i>F</i>	.482
<i>df1</i>	6
<i>df2</i>	64019.321
<i>p</i>	.822

Table 25 below shows the results of the Bartlett's test ($p = .086$) and Table 26 displays the correlations between the dependent variables. The researcher accepted the non significant ($p = .086$) result for Bartlett's Test of Sphericity since the correlations for Reflection and Critical Reflection were strong enough (.261).

Table 25

Bartlett's Test of Sphericity on New RTQ Data

Likelihood Ratio	.007
Approximate Chi-Square	9.650
<i>df</i>	5
Significance	.086

Table 26

Correlation Matrix of the Dependent Variables for New RTQ Data

	1.	2.	3.
1. Habitual Action			
2. Reflection	.009		
3. Critical Reflection	-.089	.261	

Final Analysis of Data for Research Question Two

A data analysis was conducted on the data to test the effect of a reflective practice treatment on high school science students' level of reflective thinking. A multivariate analysis of variance (MANOVA) was conducted using three of the four dependent variables included in research question two, the subscales Habitual Action, Reflection, and Critical Reflection, of the RTQ. The independent variable was program type with two levels, the reflective practice treatment and the traditional instruction as comparison.

Effects of reflective practice on the dependent variables. A Wilks' Lambda (Meyers, et al., 2006) was performed using the three dependent variables. There was a statistically significant difference, $F(3, 92) = 3.457, p = .020$, partial $\eta^2 = .101$, between the means of the treatment and comparison groups with a Bonferroni correction that sets the alpha set at $p < .025$. A Bonferroni adjustment that lowers the alpha level protects against Type I errors in significance interpretation suggests a more stringent p value than typically considered acceptable in behavioral science studies ($p < .05$). The Bonferroni correction divides the accepted significance value by the number of statistical analyses undertaken (Meyers, Gamst, & Guarino, 2006). The alpha value was set at $p = .025$, by dividing the initial alpha level of .05

by the number of times a specific set of data were used (.05/2). The data for research question two were derived from the four subscales of the RTQ. Two of these subscales, Reflection and Critical Reflection, were used again in research question three. Table 27 displays the outcomes from the MANOVA. Since the overall Wilks' Lambda was significant ($p = .020$), the non directional hypothesis was accepted.

Table 27

Multivariate Tests for Research Question Two

				Hypothesis	Error		Partial Eta
Effect		Value	<i>F</i>	<i>df</i>	<i>df</i>	<i>p</i>	Squared
Intercept	Wilks' Lambda	.026	1160.801	3.000	92.000	.000	.974
Group	Wilks' Lambda	.899	3.457	3.000	92.000	.020*	.101

Note. *Significant at the $p < .025$ level.

Each dependent variable was then analyzed using the Tests of Between-Subject Effects to determine differences between the two levels of the independent variable, treatment and comparison. Group differences were significant ($p = .007$) for the subscale of Reflection. Table 28 presents the differences between groups.

Table 28

Tests of Between-Subjects Effects for RTQ Posttests

Dependent Variable	Type III Sum of Squares	Mean Square	<i>F</i>	<i>p</i>	Partial Eta Squared
Habitual Action	2.423	2.423	2.988	.087	.031
Reflection	4.704	4.703	7.679	.007*	.076
Critical Reflection	.315	.315	.391	.533	.004

Note. *Significant at the $p < .025$ level.

Group means reveal that students in the treatment group scored significantly higher $F(4, 91) = 4.703, p = .007$ on the Reflection subscale of the RTQ ($M = 3.70, SD = .696$) than students in the comparison group ($M = 3.26, SD = .739$).

Equal variances across groups. The Levene's Test of Error Variances checks for homogeneity of variance violations for each dependent variable. After analyzing the new data, equal variances can be assumed across groups because even though results were statistically significant at the $p < .05$ level for the subscale of Reflection, frequencies are equalized by adjusting the group size. A significant Levene's does not violate equality of variance when group frequencies are equal (Meyers, et al., 2006). Table 29 shows the values for the Levene's Test for each dependent variable on the adjusted data.

Table 29

Levene's Test of Equality of Error Variances for RTQ Posttests

	<i>F</i>	<i>p</i>
Habitual Action	.617	.434
Reflection	4.089	.046*
Critical Reflection	.363	.548

Note. (*df*1 = 1, *df*2 = 94). *Significant at the $p < .05$ level

Research question two findings summary. Research question two asks, “Is there a significant difference in the level of reflective thinking as measured by the mean scores of the *Reflective Thinking Questionnaire* (RTQ) subscales (Habitual Action, Understanding, Reflection, and Critical Reflection) in high school science students who participate in a reflection program on classroom learning experiences and those who do not?”

The treatment group (reflective practice group) had a sample size of $n = 59$ that was reduced to $n = 48$ after outliers were dropped and group size was reduced to control for equality of variance by matching frequencies with the comparison group. The size of the comparison group (no reflective practice) was $n = 54$ on at the start of the study but was reduced to $n = 48$ once outliers were dropped from the data. A multivariate analysis of variance (MANOVA) was applied to three of the four subscales of the RTQ (Habitual Action, Reflection, and Critical Reflection) which served as the multiple dependent variables. The subscale of Understanding was removed from study due to significant differences in the pretests analysis and continued violations in normality on posttest analysis. The independent variable, program type, had two levels being (a) reflective practice implemented and (b) no reflective practice implemented. Wilks' Lambda allowed for the evaluation of differences on independent variables in the population on the dependent variables.

After finding no pretest differences, the multivariate test for posttest scores revealed a statistical significance ($F(3, 92) = 3.457, p = .020, \text{partial } \eta^2 = .101$, small) in the participants' level of reflective thinking, as measured by the RTQ, after the treatment. A test of between-subjects effects showed that students in the treatment group ($M = 3.70$) scored significantly higher ($F(3, 92) = 7.69, p = .007, \text{partial } \eta^2 = .076$, small) on the subscale of Reflection than the students in the comparison group ($M = 3.26$). This suggests the two groups, (a) reflective practice and (b) no reflective practice, displayed posttest differences in their reflective thinking level after the 16-week administration of the treatment (reflective practice) when measured with the RTQ.

Research Question Three Data Analysis

According to the third research question, three separate hierarchical multiple linear regression procedures (Meyers, et al., 2006) were used to determine if the predictor variables of reflection and critical reflection predicted the critical thinking dispositions of Mental Focus, Cognitive Integrity, and Scholarly Rigor, after accounting for the variance in program participation.

Assumptions for Research Question Three

As described earlier, an extreme values test using SPSS was conducted to detect outliers (Meyers et al., 2006) on the data from both the CM3 and the RTQ subscales. Based on the recommendation of Hair, Anderson, Tatham, and Black (1998), outliers were removed if they were ± 2.0 standard deviations from the mean. A total of 10 outliers were initially removed, four from the treatment group and six from the comparison group. These outliers were case numbers 02, 18, 36, and 43 from the treatment group and case numbers 63, 64, 76, 103, 111, and 113 from the comparison group.

Once the outliers were removed, assumptions were checked. The assumptions of normality, linearity, homoscedasticity, and equality of variance were investigated with research question one (CM3) and research question two (RTQ) and again here.

Normality. The shape and distribution of the variables should relate to a normal distribution, or resemble a bell curve. For this assumption, the skewness and kurtosis for each variable were assessed. Since all values were between the absolute value of ± 1.0 , the data, seen in Table 30, were acceptable for the normality assumption (Meyers, et al., 2006).

Table 30

Descriptive Statistics for Posttests of the CM3 and RTQ Independent Variables with Respect to Each Dependent Variable

Dependent Variable	Research	Standard			
	Group	Mean	Deviation	Skewness	Kurtosis
CM3 Mental Focus	Treatment	27.35	8.31	-.017	-.603
	Comparison	26.76	7.27	.600	-.354
CM3 Cognitive Integrity	Treatment	33.31	7.63	-.715	.507
	Comparison	31.05	8.04	.064	-.205
CM3 Scholarly Rigor	Treatment	27.16	6.99	-.041	-.832
	Comparison	28.09	4.92	.220	-.372
RTQ Reflection	Treatment	3.68	.699	-.824	.722
	Comparison	3.26	.739	-.106	-.693
RTQ Critical Reflection	Treatment	2.64	.861	.205	-.407
	Comparison	2.55	.924	.446	-.434

Note. Treatment group $n = 55$; Comparison group $n = 48$.

Linearity. Linearity means that the amount of change between scores on two variables are constant for the entire range of scores for the variables. By checking correlations between variables (Pearson $r > .05$) and by visually inspecting scatter plot graphs and histograms across all variables, no curvilinear relationships were observed for any of the dependent variables (Meyers, et al., 2006) therefore, this assumption was not violated.

Homoscedasticity. Observations of scatterplot graphs showed an acceptable residual output and dispersion of errors or predictions, as indicated by rectangularity within the residuals, were equal for all predicted dependent variable scores (Meyers, et al., 2006). The researcher proceeded with further analysis since the assumption of homoscedasticity was not violated according to Stevens (2002).

Correlations. Based on the recommendations of Meyers et al., (2006), a correlation matrix was analyzed prior to conducting the multiple linear regression procedures. The interrelationships of all variables were examined. The three subscales of the CM3 were moderate to strongly correlated with each other ($p < .01$). There was a low positive relationship between the RTQ subscale of Reflection and the CM3 subscales of Mental Focus and Scholarly Rigor ($p < .05$). There was little to no correlation between the RTQ subscale of Critical Reflection and the CM3 subscales. There was a strong positive correlation between the RTQ subscale of Reflection and the RTQ subscale of Critical Reflection ($p < .01$). Table 31 shows the exact values of the correlations for all variables in the regression analysis. Since most of the values are correlated with each other, but below a value of .60, this assumption is satisfied (Meyers, et al., 2006).

Table 31

Correlation Matrix of the Variables in Regression Analysis

	1.	2.	3.	4.	5.
1. CM3 Mental Focus					
2. CM3 Cognitive Integrity	.390**				
3. CM3 Scholarly Rigor	.570**	.488**			
4. RTQ Reflection	.212*	.151	.204*		
5. RTQ Critical Reflection	.032	.013	.136	.253**	
6. Instructional Group	-.038	-.143	.078	.252**	.047

Note. * $p < .05$ level (2-tailed) ** $p < .01$ level (2-tailed)

Multicollinearity considerations. Based on the recommendation of Meyers et al., (2006) the collinearity statistics and diagnostics output were examined before reporting any significant findings of the predictors and of the models. Tolerance values were analyzed to be greater than .01; therefore multicollinearity was not in violation. When examining the violation inflation factor (VIF) statistic, all values were less than 10, verifying the absence of Multicollinearity. Table 32 displays the collinearity diagnostics for each of the predictor variables, Reflection and Critical Reflection, with the criterion variables of the CM3.

Table 32

Collinearity Statistics of Regression Variables

	RTQ Reflection		RTQ Critical Reflection	
	Tolerance	VIF	Tolerance	VIF
CM3 Mental Focus	.937	1.002	.998	1.068
CM3 Cognitive Integrity	.937	1.002	.998	1.068
CM3 Scholarly Rigor	.937	1.002	.998	1.068
Instructional Group	.937	1.002	.998	1.068

Relationship of Predictor Variables and Criterion Variables

Data were analyzed to determine the effects of the predictor variables (Reflection and Critical Reflection) with the criterion variables (Mental Focus, Cognitive Integrity, and Scholarly Rigor) after accounting for the variance in program participation. Three separate linear regression procedures were run to address each criterion variable with the set of predictor variables after accounting for the variance attributed to program participation. The relationship between each linear regression analysis produced two models. Model one tests the regression by accounting for program participation (group), while model two tests the effect of the predictor variables, Reflection and Critical Reflection, on the criterion variable. Regression procedures were analyzed with the alpha set at $p < .05$. Research question three did not employ a Bonferroni correction as it was considered exploratory in nature and its results were analyzed for that purpose.

Regression procedure one. The first hierarchal, enter method, multiple linear regression tested the effect of the predictor variables of Reflection and Critical Reflection on

the criterion variable of Mental Focus after accounting for the variance of the instructional group. Variables were entered in blocks. The first block consisted of the instructional group, and the second block entered the predictor variables of Reflection and Critical Reflection. The regression produced two models; model one accounted for the first block, the variance in instructional group, and model two accounted for the second block, the entered the variables of Reflection and Critical Reflection. The regression model was not significant $F(3, 99) = 1.900, p = .135$, and together, the variables in regression one explained 5.4% of the variation in students' posttest scores, indicating that together Reflection and Critical Reflection posttest mean scores did not significantly predict the mean posttest scores for Mental Focus. Within the second block, the variable of Reflection significantly ($p = .022$) predicted the variable of Mental Focus. The results of the regression analysis one are presented in Table 33 and Table 34. Table 35 displays the coefficients for the regression procedure one with the predictor variables of Reflection and Critical Reflection and a criterion variable of Mental Focus.

Table 33

Model Summary for Regression Procedure One with Mental Focus as the Criterion

Model	R	R square	Adjusted R square	Standard		
				Error of the Estimate	R square change	Sig F change
1	.038 ^a	.001	-.008	7.77716	.001	.701
2	.233 ^b	.054	.026	7.64409	.053	.067

Note. ^a Predictors: Research Group, ($df1 = 1, df2 = 101$), ^b Predictors: Research Group, Reflection, Critical Reflection, ($df1 = 2, df2 = 99$).

Table 34

ANOVA for Regression Procedure One with Mental Focus as the Criterion

Model		Sum of Squares	<i>df</i>	Mean Square	<i>F</i>	<i>p</i>
1	Regression	8.938	1	8.938	.148	.701 ^a
	Residual	6108.906	101	57.376		
	Total	6117.845	102			
2	Regression	333.066	3	111.022	1.900	.135 ^b
	Residual	5784.778	99	58.432		
	Total	6117.845	102			

Note. ^aPredictors: Research Group, ^bPredictors: Research Group, Reflection, Critical Reflection.

Table 35

Coefficients for Regression Procedure One with Mental Focus as the Criterion

Model		Unstandardized Coefficients		Standardized	<i>t</i>	<i>p</i>
		B	Standard Error	Coefficients		
				Beta		
1	(Constant)	27.354	1.123		24.368	.000
	Research Group	-.591	1.536	-.038	-.384	.701
2	(Constant)	20.176	3.684		5.477	.000
	Research Group	-1.518	1.560	-.098	-.973	.333
	Reflection	2.371	1.018	.243	2.329	.022*
	Critical Reflection	-.216	.881	-.025	-.245	.807

Note. *Significant at $p < .05$.

Regression procedure two. The second hierarchical, enter method, multiple linear regression tested the effect of the predictor variables of Reflection and Critical Reflection on the criterion variable of Cognitive Integrity after accounting for the variance of research group. Variables were entered in blocks. The first block consisted of the instructional group, and the second block entered the predictor variables of Reflection and Critical Reflection. The regression produced two models; model one accounted for the first block, the variance in instructional group, and model two accounted for the second block, the entered the variables of Reflection and Critical Reflection. The regression model was not significant, $F(3, 99) = 2.065, p = .110$, and together the variables in model two explained 5.9% of the variation in students' posttest scores, indicating that collectively Reflection and Critical Reflection posttest mean scores did not significantly predict the mean posttest scores for Cognitive Integrity. Within the second block, the variable of Reflection did significantly ($p = .048$) predict the variable of Cognitive Integrity. The results of the regression analysis two are presented in Table 36 and Table 37. Table 38 displays the coefficients for regression procedure two with the predictor variables of Reflection and Critical Reflection and a criterion variable of Cognitive Integrity.

Table 36

Model Summary for Regression Procedure Two with Cognitive Integrity as the Criterion

Model	R	R square	Standard			
			Adjusted R square	Error of the Estimate	R square change	Sig F change
1	.143 ^a	.021	.011	7.85711	.021	.149
2	.243 ^b	.059	.030	7.77912	.038	.138

Note. ^aPredictors: Research Group, (*df*₁ = 1, *df*₂ = 101), ^bPredictors: Research Group, Reflection, Critical Reflection, (*df*₁ = 2, *df*₂ = 99).

Table 37

ANOVA for Regression Procedure Two with Cognitive Integrity as the Criterion

Model		Sum of Squares	<i>df</i>	Mean Square	<i>F</i>	<i>p</i>
1	Regression	130.676	1	130.676	2.117	.149 ^a
	Residual	6235.149	101	61.734		
	Total	6365.825	102			
2	Regression	374.868	3	124.956	2.065	.110 ^b
	Residual	5990.957	99	60.515		
	Total	6365.825	102			

Note. ^aPredictors: Research Group, ^bPredictors: Research Group, Reflection, Critical Reflection.

Table 38

Coefficients for Regression Procedure Two with Cognitive Integrity as the Criterion

Model		Unstandardized Coefficients		Standardized	<i>t</i>	<i>p</i>
		B	Standard Error	Coefficients Beta		
1	(Constant)	33.313	1.134		29.374	.000
	Research Group	-2.258	1.552	-.143	-1.455	.149
2	(Constant)	27.249	3.749		7.269	.000
	Research Group	-3.061	1.588	-.194	-1.927	.057
	Reflection	2.069	1.036	.208	1.998	.048*
	Critical Reflection	-.267	.897	-.030	-.298	.766

Note. *Significant at $p < .05$.

Regression procedure three. The third hierarchical, enter method, multiple linear regression tested the effect of the predictor variables Reflection and Critical Reflection on the criterion variable of Scholarly Rigor after accounting for the variance of research group. Variables were entered in blocks. The first block consisted of the instructional group, and the second block entered the predictor variables of Reflection and Critical Reflection. The regression produced two models; model one accounted for the first block, the variance in instructional group, and model two accounted for the second block the entered variables of Reflection and Critical Reflection. The regression model was not significant, $F(3, 99) = 1.738, p = .164$ and together the variables in model three explained 5.0 % of the variation in students' posttest scores, indicating that the Reflection and Critical Reflection mean posttest scores, either individually or collectively, did not significantly predict the mean posttest

scores for Scholarly Rigor. The results of the regression analysis three are presented in Table 39 and 40. Table 41 displays the coefficients for regression procedure two with the predictor variables of Reflection and Critical Reflection and a criterion variable of Scholarly Rigor.

Table 39

Model Summary for Regression Procedure Three with Scholarly Rigor as the Criterion

Model	R	R square	Standard			
			Adjusted R square	Error of the Estimate	R square change	Sig F change
1	.078 ^a	.006	-.004	5.97620	.006	.435
2	.224 ^b	.050	.021	5.90116	.044	.106

Note. ^aPredictors: Research Group, (*df*₁ = 1, *df*₂ = 101), ^bPredictors: Research Group, Reflection, Critical Reflection, (*df*₁ = 2, *df*₂ = 99).

Table 40

ANOVA for Regression Procedure Three with Scholarly Rigor as the Criterion

Model		Sum of Squares	<i>df</i>	Mean Square	<i>F</i>	<i>p</i>
1	Regression	21.895	1	21.895	.613	.435 ^a
	Residual	3607.212	101	35.715		
	Total	3629.107	102			
2	Regression	181.565	3	60.522	1.738	.164 ^b
	Residual	3447.542	99	34.824		
	Total	3629.107	102			

Note. ^aPredictors: Research Group, ^bPredictors: Research Group, Reflection, Critical Reflection.

Table 41

Coefficients for Regression Procedure Three with Scholarly Rigor as the Criterion

Model	Unstandardized Coefficients		Standardized	<i>t</i>	<i>p</i>
	B	Standard Error	Beta		
1 (Constant)	27.167	.863		31.494	.000
Research Group	.924	1.180	.078	.783	.435
2 (Constant)	21.357	2.844		7.510	.000
Group	.353	1.205	.030	.293	.770
Reflection	1.306	.786	.174	1.663	.100
Critical Reflection	.606	.680	.090	.891	.375

Chapter Summary

Chapter four presents the data and its statistical analysis related to the three research questions of the present study. The data represent the effects of a reflective practice treatment program on high school science students' critical and reflective thinking through the use of two separate MANOVA analyses and three regression procedures. The first multivariate analysis was used for the posttest critical thinking data (CM3) and the second for reflective thinking posttest data (RTQ). Regression procedures investigated the predictor variables of Reflection and Critical Reflection on the criterion variables of Mental Focus, Cognitive Integrity, and Scholarly Rigor.

Data analyses for research question one show that group differences were not significant at the $p < .025$ level for the subscales of the CM3, which measure the dispositions

of critical thinking. Findings suggest that the reflective practice treatment, as defined by this present study, did not significantly impact students' disposition towards critical thinking.

Using three of the four subscales of the RTQ, data analyses for research question two revealed that there was a statistically significant difference, $F(3, 92) = 3.457, p = .020$, partial $\eta^2 = .101$, between the means of the treatment and comparison groups. Group differences were significant for the subscale of Reflection ($p = .007$). Findings suggest that students who engage in reflective practice will have significantly higher levels of reflection than students who do not.

In addition, hierarchical regression analyses were conducted for research question three to investigate whether or not the variables Reflection and Critical Reflection predicted students' scores on the CM3's subscales of Mental Focus, Cognitive Integrity, and Scholarly Rigor after accounting for program participation. Results showed that together the variables of Reflection and Critical Reflection together do not significantly predict students' dispositions of Mental Focus, Cognitive Integrity, and/or Scholarly Rigor. However, the variable of Reflection alone did significantly predict the mean scores for the Subscales of Mental Focus ($p = .022$), and Cognitive Integrity ($p = .048$).

CHAPTER FIVE: SUMMARY AND CONCLUSIONS

The purpose of this present study was to measure the effect reflective practice had on high school science students' critical and reflective thinking. This chapter presents an overall summary of the research and a discussion of the findings as related to literature along with limitations, implications, and suggestions for future research.

Summary of the Study and Review of the Findings

Although much research exists on the benefits of reflection in adult learners, pre-service professionals, and educators (Boud et al, 1985; Herod, 2002; Mezirow, 1997; Schön 1983, 1987) very little research exists on the benefits of reflection for K-12 students. Therefore, the rationale of this study was to assess how reflection assignments in science affect high school students' critical thinking. By recognizing the role of reflection in learning and becoming familiar with the basic elements of reflective practice, students began to understand that knowledge was embedded in their learning experiences and realized the importance of this knowledge in improving their critical thinking skills (Raelin, 2002).

A sample of convenience ($n = 113$) was drawn from a population of high school students ($n = 415$). A total of three secondary education science teachers participated in the study. Two teachers were randomly assigned to the comparison group and one to the treatment group. The treatment, which was implemented over a 16-week period, required an implementation of reflective practice in the form of reflective journals, exit slips, and reflective discussions as part of the instructional method. The comparison group received traditional science instruction as usual.

Students in the treatment group were engaged in reflective practice over the duration of the treatment. Students completed approximately one reflective journal entry per week for

a total of 12 journal entries. Reflective journal entries provided students with the opportunity to think back on their science assignments from the week and write a short response to reflection prompts. The reflection prompts (Appendix G) guided them to focus on their perceived strengths and weaknesses, decisions that were made, areas of learning difficulty, questions that arose about the content, and new content that was mastered. Reflective journals were collected weekly by the researcher and written feedback was provided. On four occasions students shared their reflection with a peer who assessed the level of reflective writing using the guideline to offer constructive feedback (Appendix H). In addition to reflective journals, students in the treatment group participated in bi-weekly verbal reflection discussions and completed exit slips (Appendix I) at the end of their classes which prompted them to reflect on course content. These two reflective practice strategies offered students the opportunity for brief reflections on one particular aspect of the science lesson for that day.

Weekly meetings between the researcher and the teacher participating in the treatment group verified that the reflective practice treatment was being administered as designed. The researcher also confirmed that the teachers ($n = 2$) in the comparison group were not using reflective strategies in their science classes at four different intervals throughout the study.

Summary of Research Question One

The effect of the independent variable, type of science instruction (reflective practice or traditional), was examined with respect to the dependent variable, the subscales of the CM3: Mental Focus, Creative Problem Solving, Learning Orientation, Cognitive Integrity, and Scholarly Rigor (Giancarlo, 2010). Data were analyzed to determine if differences

existed between students who participated in reflection-based science instruction and those who participated in traditional science instruction. Data were collected using the five subscales of the *California Measure of Mental Motivation* (CM3) for both the pretest and posttest. A multivariate analysis of variance procedure (MANOVA) was conducted to examine the non-directional hypothesis that there will be significant differences in critical thinking as measured by the mean scores on the CM3 subscales (Mental Focus, Creative Problem Solving, Learning Orientation, Cognitive Integrity, and Scholarly Rigor) of high school science students who participated in a reflection program on classroom learning experiences and those who did not. All data were cleaned, outliers were dropped, and assumptions were checked for both pre and posttest scores. A Bonferroni adjustment set the alpha value lower than at the standard level of $p = .05$, to the level of $p = .025$, because those students who participated in research question one also participated in research question two.

Findings for research question one. With no pretest differences between groups, this posttest multivariate analysis revealed no statistical significance ($F(5, 90) = 2.67, p = .027$) in the participants' critical thinking dispositions after the treatment. This suggests the two groups, (a) reflective practice and (b) no reflective practice, displayed no differences in their critical thinking dispositions after the 16-week administration of the treatment (reflective practice) when measured with the CM3 as the pretest and posttest and using an alpha value set at $p < .025$.

Summary of Research Question Two

The effect of the independent variable, type of science instruction (reflective practice or traditional), was examined with respect to the dependent variable, the subscales of the RTQ: Habitual Action, Understanding, Reflection, and Critical Reflection (Kember et al., 2000). Data were analyzed to determine if differences existed between students who participated in reflection-based science instruction and those who participated in traditional science instruction.

Data were collected using the four subscales of the *Reflective Thinking Questionnaire* (RTQ) for the pretest and posttest. All data were cleaned, outliers were dropped, and assumptions were checked for both pre and posttest scores. For this research question, a multivariate analysis of variance procedure (MANOVA) (Meyers, et al., 2006) was conducted on three of the subscales, (Habitual Action, Reflection, and Critical Reflection) to examine the non-directional hypothesis that there will be significant differences in level of reflective thinking as measured by the RTQ for high school science students who participated in a reflection program on classroom learning experiences and those who did not. As the subscale of Understanding showed a significant difference on the pretest *t*-test, and violated the assumption of normality, the researcher removed the subscale of Understanding from the study. There were no other pretest mean differences. A Bonferroni adjustment was used to set the alpha lower than at the standard level of $p < .05$ to $p < .025$ because the participants from data used in research question two were also those participants from research question one.

Findings for research question two. The multivariate test for the posttest subscales of Habitual Action, Reflection, and Critical Reflection, revealed that there was a statistically significant difference, $F(3, 92) = 3.457, p = .020$, partial $\eta^2 = .101$ (small), between the

means of the treatment and comparison groups with the alpha set at $p < .025$. Since the overall Wilk's Lambda was significant ($p = .020$), the non-directional hypothesis was accepted. Group means revealed that students in the treatment group scored significantly higher $F(4, 91) = 4.703, p = .007$ on the Reflection subscale of the RTQ ($M = 3.70, SD = .696$) than students in the comparison group ($M = 3.26, SD = .739$). No other analysis indicated significant differences between the groups.

Summary of Research Question Three

The extent and manner in which the variables of Reflection and Critical Reflection, either together or individually, predicted the critical thinking variables of Mental Focus, Cognitive Integrity, and Scholarly Rigor, after accounting for the variance in program participation were examined. Data were collected and analyzed using posttest scores of selected subscales from the CM3 (Mental Focus, Cognitive Integrity, and Scholarly Rigor) and from the RTQ (Reflection and Critical Reflection). Three separate hierarchical, enter method, linear regressions (Meyers, et al., 2006) were conducted to address the relationship between each of the criterion variables, Mental Focus, Cognitive Integrity, and Scholarly Rigor, and the predictor variables of Reflection and Critical Reflection.

Findings for research question three. For each of the three hierarchical regression procedures, variables were entered in blocks. The first block consisted of the instructional group, and the second block added the predictor variables of Reflection and Critical Reflection to the procedure, using the enter method. The researcher employed an exploratory procedure by entering the variables of Reflection and Critical Reflection as predictor variables in block two so that the significance of either or both of these variables could be determined after accounting for the variance of program participation.

Each regression produced two models; model one accounted for the first block, the variance in instructional group, and model two accounted for the second block which included the variables of Reflection and Critical Reflection.

The regression model to predict the criterion variable of Scholarly Rigor was not significant, $F(3, 99) = 1.738, p = .164$. After accounting for variance in program participation, the variable of Reflection significantly predicted the mean scores of the criterion variables of Mental Focus and Cognitive Integrity, as measured by the CM3. For these analyses, 5.4% (Mental Focus) and 5.9% (Cognitive Integrity) of the variation in students' posttest scores were predicted. When entered into the same block with Critical Reflection, the variable Reflection significantly predicted the mean scores of Mental Focus ($p = .022$) and the mean scores of Cognitive Integrity ($p = .048$), respectively.

Comparisons and Contrasts of Findings Related to the Literature Review

The review of the literature presented in chapter two proposes that critical thinking, reflection, and reflective practice in education have a theoretical foundation in the works of Dewey (1933) and Schön (1983). Educators recognize the importance of critical thinking as a learning outcome necessary to prepare students for success beyond high school. In education, critical thinking requires the use of reflection, rationality, and decision making as well as identifying it as an important process of problem solving (Ennis, 1991). Although reflection is widely written about by many theorists (Boud et al., 1985; Bruner, 1966; Marzano, 2001; Schön, 1983) and its effectiveness has been researched in adult pre-service professions (Cormish & Jenkins, 2012; Kember et al., 2006; Osterman, 1990; Schön, 1987; Taylor-Haslip, 2004; Uline, et al., 2004), very little research exists on its use in the K-12

education setting. This dissertation expands on the gaps found in the literature related to reflection and critical thinking in high school level science.

Research Question One

The CM3 (Giancarlo, 2010) was used to examine the dispositions towards critical thinking skills of high school science students after a 16-week treatment of reflective practice. As noted in the findings, there were no statistically significant differences between the treatment group and the comparison group after the completion of the study. Potential explanations include the length of the study, time of year the study took place, and the sample size ($n = 48$, comparison group; $n = 55$, treatment group). This research study took place over the course of 16 weeks. Changes in attitudes and dispositions require a personal shift in thinking and approach. Since dispositional variables are relatively stable across time and difficult to modify (Scholl, 2008), this personal shift may require a longer amount of exposure to the treatment in order to effect change in critical thinking. In addition, this study took place during the second semester of schooling. As the end of the year approached in May, students became more focused on extracurricular activities, and attendance waned. In addition, sample sizes were on the small side for this study. Sample sizes of over 100 participants per group (Meyers, et al., 2006) may have resulted in less outliers and violations in normality or error variances.

Although prior studies have found that reflection significantly improved academic learning and achievement (Phan, 2009; Pivovar, 2010), along with goal setting and revision of work (Greenwood, 2010), prior empirical research focusing on the effect of reflection on critical thinking is minimal. The findings from the present study add to the body of knowledge with the suggestion that reflective practice (as designed in this present study) did

not change science students' current dispositions towards critical thinking over a 16-week time frame, when the students were asked to participate in reflective practice using reflective journals, exit slips, and participate in verbal reflective discussions on course content, and when the critical value was related to $p < .025$.

Research Question Two

The RTQ was used to examine the level of reflective thinking of high school science students after a 16-week treatment of reflective practice. As noted in the findings, there were statistically significant differences between the treatment group and the comparison group after the completion of the study for the subscale of Reflection. This finding adds to the body of research by providing quantitative data for the study of the use of reflection in education along with supporting the work of others on the use reflection in the K-12 educational setting (Greenwood, 2010; Pivovar, 2010; Valkanova & Watts, 2007).

Additionally, these findings support the work of Kember et al. (2000) regarding the construct of reflection. The treatment group scored significantly higher on the Reflection subscale indicating that these students did think about what they were doing, considered alternative ways to approach their learning experiences, and looked for areas to improve for the future. The comparison group scored significantly lower on this subscale which shows a lack of inclination to question the way things are done or to try and think of alternative ways to accomplish tasks (Kember et al., 2000). The successful improvement in the level of reflective thinking supports the treatment components researched in the formulation and design of this study which include the use of reflective journals (Chirema, 2006; Correia & Bleicher, 2008; Davis, 2003; Henderson, et al, 2004; Taylor-Haslip, 2004; Uline, et al.,

2004), exit slips (Leigh, 2012), and verbal reflective discussions (Henderson et al., 2004; Jindal-Snape & Holmes, 2009; Pivovar, 2010; Tsang, 2010; Yacoubian & BouJaoude, 2010).

Research Question Three

Regression analyses were conducted for research question three to investigate whether or not the RTQ variables, Reflection and Critical Reflection, either together or individually predicted students' scores on the CM3's subscales of Mental Focus, Cognitive Integrity, and Scholarly Rigor, after accounting for program participation. As noted in the findings, the variable of Critical Reflection did not significantly predict students' dispositions of Mental Focus, Cognitive Integrity, or Scholarly Rigor. However, the variable of Reflection did significantly predict the variables of Mental Focus ($p = .022$) and Cognitive Integrity ($p = .048$).

Research question three was asked as an exploratory piece on the part of the researcher and sought to discover if students' levels of reflective thinking could be a predictor of their dispositions towards critical thinking. There is no prior literature evidence to suggest that that the variables of Reflection and Critical Reflection could predict students' dispositions of Mental Focus, Cognitive Integrity, or Scholarly Rigor, however, critical thinking, reflection, and reflective practice have a theoretical foundation based on the work of Dewey (1933). This theoretical foundation suggests that students construct their own understanding and knowledge through experiences and reflection on those experiences. Dewey described reflection as a meaning-making process that moves the learner from one experience into the next with deeper understanding of its relationships and connections to other experiences and ideas. Whereas, Ennis (1991) defined critical thinking to be reasonable reflective thinking that is focused on deciding what to believe or do. Critical

thinking involves a wide range of thinking skills leading to a desirable outcome. It requires the use of reflection, rationality, and decision making. Reflection provides students the opportunity, when thinking critically, to step back and consider how to actually solve a problem and to draw on past experiences when making decisions. Therefore, reflection is a crucial element in the critical thinking process.

Findings from research question three suggest that students who have a high level of reflective thinking, as measured by the subscale of the RTQ, will be more focused, attentive, and persistent when engaged in a mental activity; will be comfortable with challenging and complex tasks; and will enjoy the interaction with others of varying viewpoints in the search for truth or best decision. Results for research question three should be interpreted with caution as the researcher conducted the statistical analyses without a Bonferroni adjustment as it was exploratory in nature.

Implications for Education

According to Mezirow (1997), the essential learning required to prepare a productive and responsible adult for the 21st century must empower the individual to think as an autonomous agent rather than to act uncritically on the received ideas and judgments of others. By engaging students in reflective activities, they were provided with opportunities to consider their actions and evaluate them in the context of various science activities. Reflective journals assisted students in making connections between their learning experiences and relating them to subject matter content. Through reflection, students developed the metacognitive elements necessary to think and plan how they may do things differently in the future based on either their success or failures at an activity.

With the development of an instructional method that embeds reflection into content area learning activities, such as science, educators have an educational foundation that encourages students to become autonomous, reflective, and socially responsible thinkers. Reflective practice activities, such as journals and exit slips, can provide educators with a form of assessment that monitors individual development and progress and can be readily used to inform future instruction. Additionally, written reflections that require students to critique, take objective positions, and to write with logic, coherence, and knowledge meet the new advances in learning standards known as Common Core (CCSSI, 2012).

Limitations of the Study

The limitations of a study are those characteristics of design or methodology that affect or influence the application or interpretation of the results. There are several limitations to this study in terms of internal validity threats as well as external ecological threats. The internal threats of subject characteristics, maturation, and testing, along with the external threats of population validity; and the ecological threats of novelty, disruption and the Hawthorne effect are addressed below.

Internal Validity Threats

Subject Characteristics. This threat occurs when the research subjects selected have differing characteristics from one another in unintended ways that relate to the variables being studied (Gall, Gall, & Borg, 2007). This was a quasi-experimental study where participating teachers were randomly assigned to either the treatment or the comparison group. Since participants were neither randomly selected from the accessible population, nor randomly assigned to either condition for this study, this was a potential concern for the researcher. The researcher tried to control this by using a sample size of at least ($n = 50$) for

each of the treatment and comparison groups. Due to the limited number of consent letters returned, the treatment and the comparison groups differed by grade level. The treatment group ($n = 59$) consisted of heterogeneous students' enrolled in general level Physics and were comprised of 11th and 12th grade students. The comparison group ($n = 54$) consisted of a mix of students in Honors Biology and Special Education Earth Science and were comprised of 9th and 10th grade students. Other than grade level, the researcher ensured that the groups were as equivalent as possible at the start of the study because each intact class from both the treatment and comparison groups was balanced with respect to number of participants and gender. There were no known differences between groups concerning the dependent variables or the impact of the treatment, as prior research does not exist that indicates that students at the 11th and 12th grade level possess different reflective thinking abilities as compared to students at the 9th and 10th grade level.

To address this threat the RTQ, a measure of the level of reflective thinking, which was administered as part of the pre and posttest, was scored immediately and was analyzed for any significant differences between the groups. No significant differences were found between the groups for the subscales Habitual Action, Reflection, and Critical Reflection. The subscale of Understanding had a significant difference ($p < .001$) between the comparison group of 9th and 10th grade students ($M = 4.36$, $SD = .513$) and the treatment group of 11th and 12th grade students ($M = 3.31$, $SD = 1.06$). Due to the significant differences between groups on the pretest and the violations of normality on the posttest, the mean scores for Understanding were removed from the study.

Maturation. This threat occurs when physical or psychological changes in the research participants occur (Gall, et al., 2007). This was a potentially moderate threat in the

study. As the school year ends, the older students of the treatment group, most specifically the senior class, had the potential to become less motivated towards completing work as their focus shifted towards graduation, college acceptance, and their collegiate future. The researcher addressed this threat by monitoring the attendance records of students in the treatment group to ensure that the components of the study were completed by the students. The average number of students absent per day during the last two weeks of the study was six students per day (Table A, Appendix J). The researcher met with the treatment group participating teacher daily at this point to document absenteeism and to ensure that a good faith attempt was made to provide students with make-up work that included the same reflective elements of the study.

Testing. In an experimental design with a pretest and a posttest that are similar, students may show an improvement simply as an effect of their experience with the pretest (Gall, et al., 2007). This is a threat of students learning from the test. It is possible that this could have been a low-level threat for this study. Since the researcher used the same instruments for the pretest and posttest, this threat was addressed by ensuring that the instruments used for the pretest and the posttest had high validity and reliability, and that the minimum time between tests was at least 16 weeks.

External Validity Threats

Population Validity. One type of population validity is the extent to which one can generalize from the experimental sample to a defined population. By choosing students from the same demographics, the researcher can generalize findings to other populations, such as a sample of high school students in a suburban district with predominantly Caucasian students from families with similar incomes.

Threats to Ecological Validity

Hawthorne Effect. This threat occurs when students are aware that they are participating in a study, are aware of the study's hypothesis, or may perceive that they are receiving special treatment which may cause a change in behavior (Gall, Gall & Borg, 2007). This had the potential to be a medium level threat. The researcher stressed to the teacher of the treatment group at the time of the study not to overemphasize the study or give any extra special attention to the participants. All members of the class, whether or not they agreed to participate in the study, completed the elements of the treatment as part of the course curriculum. The participating teacher awarded classwork credit to all students for completion of reflective journals and exit slips.

Novelty and disruption effect. This threat occurs when the students perform better because the treatment is perceived as novel or new and exciting. This can also happen in reverse, when the treatment disrupts the normal routine and the results are ineffective (Gall, et al., 2007). This threat had the potential to be at a high level. Since reflective practice was a new concept to students in the treatment group, they either may have been more motivated because it was something new, or may have resented it because it was different from regular class procedures. The researcher addressed this threat in two ways. First, the treatment was administered by the teacher in such a way that normal class routines were followed as closely as possible, the reflective practice elements were counted as a proportional part of all students' homework grades, and that the expectations of the teacher remained the same. Secondly, the treatment was administered over 16 weeks so that novelty and disruption effects wore off before the experiment was concluded.

Suggestions for Future Research

The purpose of this study was to measure the effect of a reflective practice instructional method in core curriculum science classes on students' critical and reflective thinking. This study investigated this topic with three separate research questions. The results of each research question are used to present multiple ideas and suggestions for future research.

Research Question One

Research question one sought to examine the critical thinking skills of high school science students after a 16-week treatment of reflective practice. Opportunities exist for future research to address several areas of this study. These could include extending the study over the course of an entire school year rather than just the second half of the year, increasing the sample size to include students from all grade levels, focusing the study on only one grade level, or comparing individual grade levels. Future research is needed to determine if dispositions towards critical thinking vary by grade level. A repeated measures design could also determine if students are more positively disposed to critical thinking at varying times in the school year.

Research Question Two

Research question two examined the level of reflective thinking of high school science students after a 16-week treatment of reflective practice. Although there was a modicum of success in this area, more research is needed to continue the growth of knowledge on the benefits of reflection in the K-12 setting. Suggestions for future research in this area are similar to research question one: extending the study over the course of an entire school year rather than the second half of the year, increasing the sample size to

include students from all grade levels, focusing the study on only one grade level, or comparing individual grade levels. More research is needed to determine at which grade level, if at all, students begin their growth in reflective thinking. Additionally, the elements of the reflective practice treatment (journals, exit slips, verbal discussions) could be analyzed to determine if one component affected the increase in reflective thinking more than the others.

Research Question Three

Research question three investigated whether or not the RTQ variables, Reflection and Critical Reflection, predicted students' scores on the CM3 subscales of Mental Focus, Cognitive Integrity, and Scholarly Rigor after accounting for program participation. As stated earlier, critical thinking involves a wide range of thinking skills leading towards a desirable outcome. It requires the use of reflection, rationality, and decision making (Dewey, 1933). Reflection provides students the opportunity, when thinking critically, to step back and consider how to actually solve a problem and to draw on past experiences when making decisions. Therefore, reflection is a crucial element in the critical thinking process and more research is needed in this area to understand how reflection and critical thinking are related, and their potential impact in the education setting. An extension of this study could use the regression analysis to include the other variables of the RTQ, (Habitual Action and Understanding) as predictors. Additionally, the remaining variables of the CM3, (Learning Orientation and Creative Problem Solving), could be added as criterion variables.

Chapter Summary

In summation, this study was designed to investigate the impact of a reflective practice treatment on the critical and reflective thinking of high school science students.

There is limited empirical research on the use of reflection in K-12 education and relating reflection to critical thinking. The research shows that there is a clear theoretical connection to the construct of constructivism (Dewey, 1935; Schön, 1983, 1987) and that the reflective instructional methods developed in the treatment are supported by research (Boud et al., 1985; Chirema, 2006; Correia & Bleicher, 2008; Davis, 2003; Henderson et al., 2004; Jindal-Snape & Holmes, 2009; Leigh, 2012; Taylor-Haslip, 2004; Tsang, 2009; Uline et al, 2004; Valkanova & Watts, 2007; Yacoubian & BouJaoude, 2010) . Significant findings in this study suggest there is a link between reflective practice in the form of reflective journals, exit slips, and verbal discussions, and students' improved level of reflective thinking. Further research is needed in terms of finding ways to improve critical thinking as well as to investigate the relationship between critical thinking and reflection.

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Appendix A: Letter and Consent Form (Superintendent)



WESTERN CONNECTICUT STATE UNIVERSITY
Department of Education & Educational Psychology
181 White Street
Danbury, CT 06810

October 2012

Dear _____, Assistant Superintendent of _____ Schools,

As you know, I have been a science teacher in _____ for 6 years and am currently enrolled as a doctoral student at Western Connecticut State University. **I am seeking district permission to carry out a dissertation research study at the high school level in the _____ Central School District.**

The study will begin on or about January 21, 2013 and will continue for 16 weeks to conclude on, or about, May 10, 2013. Two quantitative instruments, The *California Measure of Mental Motivation* (CM3), and the *Reflective Thinking Questionnaire* (RTQ) will be used in this study to assess critical thinking and the level of reflective thinking. These assessments will provide valuable information about the effects of reflections in science on critical thinking. The instruments will be administered via paper and pencil, and will take approximately 20 minutes to administer. The assessments will be administered during the students' science class on a day that is designated as the lab block period consisting of 84 minutes.

Participating students will be asked to complete the CM3 and the RTQ as a pretest on the first day of the study. Students will then participate in a brief lesson on reflection, how to write a reflective piece on a learning experience, and how to engage in reflective discussions. The lesson on reflection, along with examples and modeling, will take place during the students' science class and will be conducted by the researcher, myself. Students in the class will be asked to participate in three types of reflection during the course of the study. First, they will be asked to write weekly formal reflections for selected learning experiences they participate in for the 16 weeks they are involved in the study. The expected number of written reflections, to be completed is 16. Reflections will be written in a journal during regular class time. Additionally, students will participate in informal verbal class reflections initiated by the teacher approximately twice per week. Finally, students will complete exit cards two times per week for a brief reflection on the class activity. Upon conclusion of the study, the CM3 and the RTQ will be administered again as a post-test.

This study will allow for an assessment of critical thinking as part of a program implementation of reflection on science learning experiences. By measuring critical thinking in high school science, educators can better understand outcomes related to reflection and critical thinking, and informed decisions can be made to enhance critical thinking in science.

This research study has been reviewed and approved by Western Connecticut State University's Institutional Review Board. Participation in this study is completely voluntary. Students who agree to participate will submit all information to the researcher. The classroom teacher will not know which students and parents have given their consent to participate in the study. Therefore, program participation will not impact a student's science grade. Privacy will be protected. Student names will be numerically coded. All student identities will be maintained in a secure location to protect confidentiality. If you have questions concerning the rights of the subjects involved in research studies please **email** the WCSU Assurances Administrator at irb@wcsu.edu and mention **Protocol Number [1213-59]** This study is valid until November, 2013.

If you have any questions, please feel free to contact me.

Sincerely,

Kathleen R. Murphy

Kathleen R. Murphy

North Salem High School- Science Dept.

kmurphy@northsalemschools.org

I agree that the study describe above can be conducted at _____ High School.

Name (Please print)

Signature

Date

Appendix B: Letter and Consent Form (Principal)



WESTERN CONNECTICUT STATE UNIVERSITY
Department of Education & Educational Psychology
181 White Street
Danbury, CT 06810

October 2012

Dear _____, Principal

As you know, I have been a science teacher in _____ for 6 years and am now a doctoral student at Western Connecticut State University. I am seeking district permission to carry out a dissertation research study at the high school level in the _____ Central School District.

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Participating students will be asked to complete the CM3 and the RTQ as a pretest on the first day of the study. Students will then participate in a brief lesson on reflection, how to write a reflective piece on a learning experience, and how to engage in reflective discussions. The lesson on reflection, along with examples and modeling, will take place during the students' science class and will be conducted by the researcher, myself. Students in the class will be asked to participate in three types of reflection during the course of the study. First, they will be asked to write weekly formal reflections for selected learning experiences they participate in for the 16 weeks they are involved in the study. The expected number of written reflections, to be completed is 16. Reflections will be written in a journal during regular class time. Additionally, students will participate in informal verbal class reflections initiated by the teacher approximately twice per week. Finally, students will complete exit cards two times per week for a brief reflection on the class activity. Upon conclusion of the study, the CM3 and the RTQ will be administered again as a post-test.

This study will allow for an assessment of critical thinking as part of a program implementation of reflection on science learning experiences. By measuring critical thinking in high school science, educators can better understand outcomes related to reflection and critical thinking, and informed decisions can be made to enhance critical thinking in science.

This research study has been reviewed and approved by Western Connecticut State University's Institutional Review Board. Participation in this study is completely voluntary. Students who agree to participate will submit all information to the researcher. The classroom teacher will not know which students and parents have given their consent to participate in the study. Therefore, program participation will not impact a student's science grade. Privacy will be protected. Student names will be numerically coded. All student identities will be maintained in a secure location to protect confidentiality. If you have questions concerning the rights of the subjects involved in research studies please **email** the WCSU Assurances Administrator at irb@wcsu.edu and mention **Protocol Number [1213-59]**. This study is valid until November, 2013.

If you have any questions, please feel free to contact me.

Sincerely,

Kathleen R. Murphy

Kathleen R. Murphy

North Salem High School- Science Dept.

kmurphy@northsalemschools.org

I agree that the study describe above can be conducted at _____ High School.

Name (Please print)

Signature

Date

Appendix C: Letter and Consent Form (Teacher)



WESTERN CONNECTICUT STATE UNIVERSITY
Department of Education & Educational Psychology
181 White Street
Danbury, CT 06810

October 2012

Dear Teacher,

I am currently enrolled in the doctoral program for Instructional Leadership at Western Connecticut State University. This program requires that I design and implement a dissertation research study. For this I am conducting a research study this spring. The purpose of this 16 week study is to determine the effects of a reflection implementation on critical thinking for high school science students.

The study will begin on or about January 21, 2013 and will continue for 16 weeks to conclude on, or about, May 10, 2013. Two quantitative instruments, The *California Measure of Mental Motivation* (CM3), and the *Reflective Thinking Questionnaire* (RTQ) will be used in this study to assess critical thinking and the level of reflective thinking. These assessments will provide valuable information about the effects of reflections in science on critical thinking. The instruments will be administered via paper and pencil, and will take approximately 20 minutes to administer. The assessments will be administered during the students' science class on a day that is designated as the lab block period consisting of 84 minutes.

Participating students will be asked to complete the CM3 and the RTQ as a pretest on the first day of the study. Students will then participate in a brief lesson on reflection, how to write a reflective piece on a learning experience, and how to engage in reflective discussions. The lesson on reflection, along with examples and modeling, will take place during the students' science class and will be conducted by the researcher, myself. Students in the class will be asked to participate in three types of reflection during the course of the study. First, they will be asked to write weekly formal reflections for selected learning experiences they participate in for the 16 weeks they are involved in the study. The expected number of written reflections, to be completed is 16. Reflections will be written in a journal during regular class time. Additionally, students will participate in informal verbal class reflections initiated by yourself, at the appropriate times, approximately twice per week. Finally, students will complete exit cards two times per week for a brief reflection on the class activity. Upon conclusion of the study, the CM3 and the RTQ will be administered again as a post-test.

In agreeing to participate in the study you will be randomly selected to wither the treatment group or the comparison group. Instructors of the comparison group need only to administer the pre-tests and the post-test. Regular science instruction will continue as

normal. Instructors randomly assigned to the treatment group will be asked to administer the pre-tests and the post-test, to allow the researcher to conduct a 30 minute lesson on reflection (which includes examples and modeling for the students), and implement the treatment of reflection for a period of 16 weeks. The treatment will consist of you implementing reflection to your normal instruction in three ways, weekly reflective journals, biweekly verbal class reflections, and biweekly exit cards that reflection on the day's lesson. Training in how to implement reflection into your normal instruction will be provided by the researcher prior to the start of the treatment, as well as guidance along the way.

This study will allow for an assessment of critical thinking as part of a program implementation of reflection on science learning experiences. By measuring critical thinking in high school science, educators can better understand outcomes related to reflection and critical thinking, and informed decisions can be made to enhance critical thinking in science.

This research study has been reviewed and approved by Western Connecticut State University's Institutional Review Board. Participation in this study is completely voluntary. Students who agree to participate will submit all information to the researcher. The classroom teacher will not know which students and parents have given their consent to participate in the study. Therefore, program participation will not impact a student's science grade. Privacy will be protected. Student names will be numerically coded. All student identities will be maintained in a secure location to protect confidentiality. If you have questions concerning the rights of the subjects involved in research studies please **email** the WCSU Assurances Administrator at irb@wcsu.edu and mention **Protocol Number [1213-59]**. This study is valid until November, 2013.

Participation in this study is completely voluntary. You are free to withdraw from the study at any time. If you have any questions, please contact me via email at kmurphy@northsalemschools.org or by phone at (914) 669-5414 ext 2163.

If you agree to participate in this research study, please sign this form and return it to me.
Sincerely,
Kathleen R. Murphy
Kathleen R. Murphy
North Salem High School – Science Dept.

I wish to participate in the study mentioned above.

Teacher Participant name: (Please Print) _____

Teacher Participant Signature _____ Date: _____

Appendix D: Letter and Consent Form (Parent/Guardian)



WESTERN CONNECTICUT STATE UNIVERSITY
Department of Education & Educational Psychology
181 White Street
Danbury, CT 06810

Parent / Guardian Consent Form to Participate in a Research Study

Dear Parent or Guardian,

In an effort to enhance student work to meet the _____ District's mission of engaging students in critical and creative thinking, students will be learning about self-reflection; how they think as learners and how they can self-evaluate their work. Reflection centers on describing, analyzing, and evaluating our thoughts, assumptions, beliefs, theory base, and actions. It is thinking about a learning task after you have done it, thinking about how it applies to the content, and contextualizing it to reality.

The benefits of reflection on activities for students include improved problem solving and critical thinking skills. Through means of reflective writing pieces on learning experiences, high school science students improve their understandings of concepts, develop critical thinking and problem solving skills, and build connections to the content. Developing critical thinking skills is essential for high school students as they prepare for their future as adult problem solvers. By providing an environment where students can reflect not only on their lab experiences but how they reached their conclusions, students' critical thinking skills will improve.

Since I am currently enrolled in the doctoral program for Instructional Leadership at Western Connecticut State University, I see this as an opportunity for an educational research project for the future. I am designing and implementing a dissertation study on this work. The purpose of this 12 week study would be to determine the effects of a reflection implementation to science learning experiences on critical thinking for high school science students. The study will begin on or about January 21, 2013 and will continue for 16 weeks to conclude on or about May 10, 2013. I will be administering a two surveys to students that asks them how they think when they are learning, and assess their current level of reflection. These quantitative surveys, *The California Measure of Mental Motivation (CM3)*, and the *Reflective Thinking Questionnaire (RTQ)* will ask students to self-assess their level of reflection and critical thinking. This assessment will provide valuable information about the effects of reflections in science on critical thinking. The survey will be administered via paper and pencil, and will take approximately 20 minutes to complete.

Students will be asked to complete the survey in their science class. Next students will be given a brief lesson on reflection, thinking about their learning as it is happening, and how to write a reflective piece on their learning experiences. Students in the class will be asked to write short reflections for learning experiences in which they participate for the next few weeks. The expected number of reflections to be completed is 16. Reflections will be conducted during regular class time. Upon conclusion of the study, the surveys will be administered again as a post-test.

This research study has been reviewed and approved by Western Connecticut State University's Institutional Review Board. Participation in this study is completely voluntary. Students who agree to have their survey results be part of the study will be asked to sign an assent form and submit a parental consent form. Permission to use results is strictly voluntary, and program participation or non-participation will not impact a student's science grade. Privacy will be protected. Student names will be numerically coded. All student identities will be maintained in a secure location to protect confidentiality. Results will only be reported in aggregate form. Results will not be reported to the district or influence your child's science grade.

I wish to thank administrators of the _____ Central School District for considering participation in this study. It is hoped that results of this investigation will enable educators to better understand outcomes related to reflection and critical thinking. If you have any questions, please feel free to contact me via email at kmurphy@northsalemschools.org or phone at (914) 669-5414 ext 2163. **If you have questions concerning the rights of the subjects involved in research studies please email the WCSU Assurances Administrator at irb@wcsu.edu and mention Protocol Number [1213-59]. This study is valid until November, 2013.**

If you agree to have your child's results of the survey be part of the study, please sign the attached statement and return it to your child's science teacher by Monday, December 17, 2012.

Sincerely,
Kathleen R. Murphy
Kathleen Murphy
North Salem High School – Science Dept.

Participation in this study is completely voluntary. You are free to withdraw your child's results from the study at any time. All information is completely confidential.

I, _____, the parent/legal guardian, of the student
(printed name of parent or guardian)
minor below, acknowledge that I am **at least 18 yrs of age**, and that the researcher has explained to me the purpose this research study, identified any risks involved, and offered to answer any questions I may have about the nature of my child's participation. I voluntarily consent to my child's participation. I understand all information gathered during this project will be completely confidential.

Student/Minor's Name: _____

Printed name of Parent/Guardian: _____

Signature of Parent /Guardian: _____ Date: _____

Appendix E: Letter and Assent Form (Student)



WESTERN CONNECTICUT STATE UNIVERSITY
Department of Education & Educational Psychology
181 White Street
Danbury, CT 06810

Student Information Form to Participate in a Research Study

October 2012

Dear Student,

I am in a doctoral program at Western Connecticut State University. I am doing an exciting research study about strategies for teaching science. I would like you to be a part of my study. I will also send a permission slip home with you to give to your parents. First, I would like you to know more about my project.

The study is about the ways in which you think critically. By measuring critical thinking in high school science, teachers can better understand critical thinking, and can make better decisions about how they teach science.

I will ask you to complete a survey. This is a questionnaire about thinking skills and how mentally motivated you are to think. I will ask you complete this information two times during the next 16 weeks. Some students may be asked to complete their assignments a little differently during their science classes.

I will not use your name in the study; I will use numbers. The surveys will have nothing to do with report card grades, class participation grades, or grades from other science activities. Your survey results will not be reported to your science teacher. All of the information will be kept private. If you have any questions, please ask me.

If you would like to be in my study, please print and sign your name below:

Print student name

X _____ Date: _____

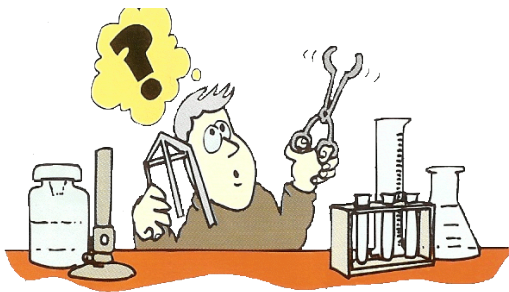
Student signature

Thank you,

Ms. Kathleen R. Murphy
North Salem High School – Science Dept.
kmurphy@northsalemschools.org

Dr. Marcia Delcourt, PhD
Coordinator, Instructional Leadership
delcourtm@wcsu.edu

APPENDIX F: Lesson on Reflection



Reflection in Science

Teacher: Ms Kathleen R. Murphy

Date of Lesson: 01-22-2013

National Science Education Standards

Content Standard A: As a result of their activities in grades 9-12, all students should develop abilities necessary to do scientific inquiry, and **understandings** about scientific inquiry

Content Standard E. Science and Technology - An understanding of science and technology establishes **connections** between the natural and designed world, linking science and technology.

New York State: Math, Science, and Technology (MST)

STANDARD 7: Interdisciplinary Problem Solving

Students will apply the knowledge and thinking skills of mathematics, science, and technology to address real-life problems and make informed decisions.

Key Idea 2: Solving interdisciplinary problems involves a variety of skills and strategies, including effective work habits; gathering and processing information; generating and analyzing ideas; realizing ideas; **making connections** among the common themes of mathematics, science, and technology; and presenting results.

Student Learning Objective(s):

The student will be able to:

Cognitive:

- Develop an understanding of what reflection is, how to reflect, and the benefits of reflecting in terms of related work in science.

•

Affective:

- Participate in lesson on reflection by sharing thoughts or ideas, asking or answering questions, and showing a respectful personal attitude.

Psychomotor:

- Complete, in writing, the lab write-up from the lesson in terms of demonstrating understanding of concepts.

Assessment:

Informal evaluations can take place in this lesson. During this lesson, the instructor will be monitoring the behavior of the students as they participate in the presentation, discussion, and sharing of ideas on reflection.

Materials/Resources:

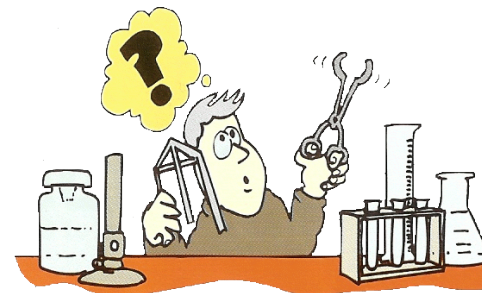
Materials:

Instructional Materials

LCD projector, Copies of Feedback Rubric, Copies of Reflection Exemplars

Resources:

Reflection PPT Created by Researcher
Guideline for Feedback on Reflective Writing Rubric

**Lesson Structure****Initiation** (2 minutes)

Begin with an introduction (if necessary) and Rationale for the lesson on Reflection

For example: *“Today I would like to share with you a topic that is very important in science, your other classes, as well as in life. This is the topic of Reflection. Reflection is very helpful to students and I would like to share with you what it is, what it means to reflect, why we should reflect, and ways to reflect.”*

Lesson Development**I. Reflection Lesson** (30 minutes)

- (Slide 1-2) Begin the PowerPoint on reflection.
- Share your personal Aha moment. Ask if any students have ever had an Aha moment themselves. If so, ask a few to share their experience.
- (Slide 3-11) Define reflection, explain how it leads to higher critical thinking, problem solving, how we can learn from reflection, and share the benefits of reflection.
- Ask students if they have ever spent any time reflecting, either in classes, at home, on an athletic teams, etc... Ask if any student would like to share their stories and the outcomes. Offer positive feedback and wherever possible connect to the concepts in the lesson thus far.
- (Slide 12). Share the ways that students can reflect.
- Ask if students have any other ideas of how to reflection. If so, let them share.
- (Slides 13-18). Discuss Reflective writing. At slide 18 pass out the copy of the reflective writing rubric and mock samples of student writing. Ask students to assess the level of reflection and share ideas with the class. Allow time for students to participate in this. (Alternative: have students pair up and work together on this).
- Share conclusion and move into a sample verbal reflection: Rapid Fire

II. Rapid Fire (5 minutes)

- Share with students this quick (fun) activity that demonstrates on way reflections can be done verbally.

Closure (3 minutes)

Wrap up the lesson with:

“What did you learn today that you didn’t know before the lesson?”

“How do you think this will help you in understanding and making connections to science concepts??”

Assess for authentic responses. Ask students to share comments. Discuss any insightful comments or ideas.

APPENDIX G: Reflection Prompts

Reflection prompts to be provided to students for their weekly written reflection entry.

Reflection Prompts

#1 - In terms of your learning experiences last week (movie, lab, exam, lecture, debate)

- What went or worked well?
- Why was this experience so positive? How did you approach your learning?
- What, if anything, went poorly? Why?
- What do YOU think you maybe could have done differently for this learning experience? What could have been done better?

#2 - In terms of your learning experiences last week (movie, lab, exam, lecture, debate)

- What did you learn during this process that you didn't know before?
- How can you apply this process and/or your approach (solution) to other similar challenges (either in school or outside of school)?
- What skills did you learn that apply to other areas of your learning?

#3 - In terms of your learning experiences last week (movie, lab, exam, lecture, debate)





- What challenges did you face when approaching this learning experience?
- Could you have approached this experience differently? Why or why not?
- What is one thing you learned from this experience?

#4 - In terms of your learning experiences last week (movie, lab, exam, lecture, debate)

- What was the best or most positive thing that happened in this class this week?
- What was the most difficult thing that happened in this class this week?
- Did you receive any compliments or criticisms? What did you learn from this?
- Think about the learning experiences from this week. What have you learned from your successes and failures?

APPENDIX H: Guideline for Feedback on Reflective Writing

Rubric for Feedback on Reflective Journal Writing

Criteria	Exemplary (4) 	Proficient (3) 	Developing (2) 	Basic (1) 
Context and Reference	Demonstrates critical reflection and awareness that the same actions and events may be seen in different contexts with different explanations. Clearly ties personal knowledge, beliefs, attitudes, and experiences into the responses and sets the context for the assignment and the reflection prompt. The writer refers to specific features of the work s/he turned in.	Demonstrates a ‘stepping back’ from events. There is consistent reflection showing various connections and awareness of learning process. For the most part, ties personal knowledge, beliefs, attitudes, and experiences into the responses and the writer sets the context for the assignment and the reflection prompt. The writer refers to specific features of the work s/he turned in.	Some evidence of reflection, occasional connection to prior knowledge or current event. Uses primarily descriptive language. Tries, but does not really succeed, in tying personal knowledge, beliefs, attitudes, and experiences into the responses. The writer makes some attempt to set the context. The writer makes vague references to the work turned in.	A simple recall of events or a summary of class. There is no discussion beyond description. Does not tie personal knowledge, beliefs, attitudes, and experiences into the responses, and s/he makes no references to the work turned in.
Depth of Reflection	The writer directly addresses the reflection prompt(s) given by the instructor, elaborates his/her points, makes real connections between the assignment and his/her learning, highlights new insights and perspectives, and/or uses techniques such as questioning, comparing, interpreting, and analyzing.	The writer addresses the reflection prompt(s) given by the instructor, and does a fairly good job with elaboration, making connections, offering new insights and perspectives, and/or uses techniques such as questioning, comparing, interpreting, and analyzing.	The writer partially addresses the reflection prompt(s) given by the instructor, and fails to sufficiently elaborate his/her points. S/he makes few connections, offers few insights and perspectives, etc.	The writer fails to address the reflection prompt(s) given by the instructor. The reflection piece contains no elaboration and is too short.
Conventions of Standard Edited English	The writer demonstrates a solid grasp of standard writing conventions (e.g., spelling, punctuation, capitalization, sentence structure, word choice, paragraphing) and uses conventions effectively to enhance readability. Errors are practically non-existent.	The writer usually demonstrates a good grasp of standard writing conventions and uses conventions effectively to enhance readability. The presence of few errors makes the piece generally enjoyable to read.	The writer shows some control over standard writing conventions. Conventions are sometimes handled well and enhance readability; at other times, errors are distracting and impair readability.	Errors in spelling, punctuation, capitalization, usage, grammar and paragraphing repeatedly distract the reader and make the text difficult to read.

Adapted and used with authors’ permission from website

The Learning Centre, The University of New South Wales © 2008 <http://www.lc.unsw.edu.au/onlib/reflect3.html>

Reflective Writing for SLCC’s Gen Ed ePortfolio: A Common Sense Rubric ©2012

<http://www.aacu.org/meetings/annualmeeting/AM12/documents/hubertCommonsenseReflectiveWritingRubric.pdf>

APPENDIX I: Exit Slip Prompts

Physics Exit Slip

PMI - Plus, Minus, Interesting

Name: _____

Write one thing that was positive today (+).

Write one thing that was negative today (-).

Write one thing that you found interesting today.

Physics Exit Slip

Action Plan

Name: _____

What was today's lesson about?

What did you learn?

What will you do with what you learned?

Physics Exit Slip

Comfort Zone

Name: _____

What are you sure that you know well?

What do you not know so well?

What do you not understand at all?

Physics Exit Slip

Stoplight

Name: _____

Describe something that you agree with.

Describe something you are not sure about.

Describe something that you disagree with.

Physics Exit Slip

Documented Learning

Name: _____

Write one thing you learned today.

Physics Exit Slip

Real World

Name: _____

Discuss how today's lesson could be used in the real world.

Physics Exit Slip

“???”

Name: _____

Write one question you have about today's lesson.

Physics Exit Slip

Group Work

Name: _____

Did you enjoy working in small groups today? Why or Why not?

Physics Exit Slip

Surprise :o

Name: _____

The thing that surprised me the most today was...

Physics Exit Slip

Explanations

Name: _____

Please explain more about...

APPENDIX J: Table A

Participant Attendance for the Components of the Reflective Practice Treatment

Table A

Participant Attendance by Percentage for Components of Reflective Practice Treatment

Week of			
Research Study	Journal Writing	Exit Slip #1	Exit Slip #2
1	89.8%	96.6%	96.6%
2	88.1%	94.9%	91.5%
3	X	X	88.1%
4	86.4%	91.5%	96.6%
5	88.1%	91.5%	X
6	X	88.1%	86.4%
7	83.0%	X	96.6%
8	94.9%	X	89.8%
9	X	86.4%	89.8%
10	86.4%	77.9%	X
11	86.4%	X	88.1%
12	86.4%	98.3%	X
13	X	89.8%	88.1%
14	81.3%	86.4%	83.0%
15	77.9%	81.3%	91.5%
16	76.2%	61.0%*	X

Note. Based on initial treatment group size ($n = 59$). An “X” indicates that the element was not completed in this week. *School event during this element explains low attendance percentage.