CRITICAL THINKING AND INTRINSIC MOTIVATION IN SECONDARY SCIENCE

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A Thesis Submitted to the
University of North Carolina at Wilmington in Partial Fulfillment
of the Requirements for the Degree of
Master of Education

Watson School of Education

University of North Carolina at Wilmington

2003

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ABSTRACT

Research was conducted on the impact of critical thinking (CRT) on student academic intrinsic motivation (IM) in science using a pre/post-test evaluation. Sixty-three students from four different southeastern North Carolina high school earth/environmental science classes were given the Watson-Glaser Critical Thinking Appraisal-Short Form (WGCTA-S) and the Children's Academic Intrinsic Motivation Inventory (CAIMI) before and after a weeklong period of instruction on critical thinking. CRT skills were taught through a variety of methods to three treatment classes using earth/environmental science content. A control group not participating in the CRT instruction received regular earth/environmental science instruction. Gender, treatment group, and motivational levels were analyzed. Results indicated that students' receiving the CRT instruction showed statistically significant increases in critical thinking ability and academic motivation toward science. Findings further supported continued research into the relationship between acquisition of CRT skills and increased student academic IM toward science.

ACKNOWLEDGMENTS

I would like to thank the faculty of the Watson School of Education for their continuous support and guidance. In particular I want to thank Jeremy Dickerson for putting me on the right path and keeping me there; Dr. Edward J. Caropreso for his tireless efforts in support of my academic goals and many many books; and Dr. Karen Wetherill who always managed to find time despite an incredibly busy schedule.

I would also like to thank the faculty of the New Hanover County School System. Their willingness to support my research has been a blessing. I would like to especially thank Tim Barker for inspiring me to become a master educator, and Lauren Fowler who generously gave up much of her time and her students in order to support my research.

DEDICATION

I would like to dedicate this work to my parents without whom this or any of my other higher education would have been impossible. They have surrounded with infinite examples of success and dedication. They have instilled in me a valuable work ethic, and a deep faith in God. I cannot express the love and admiration I have for them both. Thank you both so much.

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DEFINITION OF THE PROBLEM

Introduction

Secondary teachers face the difficult task of motivating students to learn disciplinary content on a daily basis. These teachers often compete with many distractions both within and beyond the walls of the classroom to gain and maintain the attention and interest of students. Distractions range from commonplace issues such as peer acceptance, to atypical issues such as school shootings. In this environment intrinsic motivation to learn content can be constrained or even stifled.

Most teachers have been faced with the difficult task of trying to motivate students to learn content. Often the students that present the biggest challenge to teachers are not those that push them to offer more challenging learning opportunities, but those that seldom embrace the educational opportunities presented to them. Low student motivation to learn is often cited as factor attributing to teacher burnout (Raquepaw & deHaas, 1984).

As students reach high school, they are motivated by extrinsic factors more and more. When asked to complete an assignment students immediately respond with the question, "Are you going to take a grade on this?" Rarely is there a genuine interest in mastery of the material or general interest in content. By the time they reach high school, students have begun to rely upon extrinsic motivation, and intrinsic motivation to learn has become stagnant. Academic intrinsic motivation to learn decreases starting in third grade and continues to decrease throughout high school (Cordova & Lepper, 1996; Gottfried et al, 2001). This is a reality of secondary education. The ability of any educator to identify and implement strategies fostering the development of intrinsic motivation to learn content in his or her students would be valuable.

In order to address decreasing intrinsic motivation in students, it is imperative to identify the root causes of the decline. When students who lack intrinsic motivation to learn are asked to complete a question, problem, or assignment that requires extra effort or contemplation they often to choose not complete it. However, they will respond quickly to fill in a bubble or select a memorized definition from a list. As an educator it is appropriate to ask why this is the case.

Problem Background

Differences in intrinsic motivation among students can be attributed to many conditions. On any given day a student may not be motivated due to disinterest, distraction, or illness, but when this pattern persists day after day, and is associated with whole groups of students, clearly something more pervasive maybe the cause. As students progress toward high school, extrinsic motivators such as grades and rewards supplant intrinsic motivators such as content mastery and enjoyment of learning new content. When students begin to fail to receive extrinsic rewards it can begin a cycle of decreasing intrinsic motivation. Additionally students may begin to perceive themselves as incapable or deficient in certain content areas based on other characteristics like gender. As such, they never learn to begin the difficult cognitive tasks that require critical thinking skills. Such experiences increasingly distance these students from those who have proven capable of attaining extrinsic rewards. Poor instruction with regard to critical thinking only serves to perpetuate a student's declining perception of ability, and exacerbate their distance from successful students. In order to right this situation, it is imperative that student be adequately prepared to handle more challenging cognitive tasks.

Science and Critical Thinking

Science is filled with content specific definitions, rule relationships, experimental designs, and questions of ethics and values. Critical thinking skills are often an expected outcome for instruction, and needed for success. Recent national standards for science education include critical thinking as a key element of science instruction. The National Science Educational Standards (NSES, 1995) make the following claim.

> "The new vision includes the "process of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. (NSES, 1995, ¶7)

The expectation that critical thinking will be taught in high school science is also reflected in state curriculum guides. The North Carolina Standard Course of Study (NCSCS, 2001) indicates that critical thinking is an expected outcome of science instruction. The NCSCS refers to critical thinking as follows.

> "The revised North Carolina Standard Course of Study takes students beyond science as merely a body of knowledge to science as inquiry. It requires students to combine science and scientific knowledge with scientific reasoning and critical thinking.(NCSCS, 2001, ¶ 8)

These statements reflect the importance placed on critical thinking as a component of science instruction. The scientific method is based on the ability to think critically with regard to scientific process and experimentation. However, far too often critical thinking is expected of students, but not taught to students. No potentially effective educator would give students exams intended to assess their content knowledge without first teaching them that content, but teachers often expect students to employ critical thinking skills using content knowledge without teaching them those very skills, or providing them with opportunities for practice. This only sets students up for failure and often undermines any intrinsic motivation to learn the intended content, or tackle challenging tasks. As a result critical thinking skills must be included effectively in science instruction.

Rationale for Current Research

Various factors exist that contribute to declining student motivation to learn science content as they enter high school. One such factor is poor instruction with regard to critical thinking skills in science curriculum that leads to student failure. Students who are not prepared by the teachers to accomplish curriculum goals will only become less intrinsically motivated to learn. A second factor contributing to low student intrinsic motivation is negative self-perception on the part of students have based on characteristics such as gender.

A consistent and measurable link exists between critical thinking ability and student intrinsic motivation to learn science. Definitions of critical thinking and intrinsic motivation commonly include elements closely associated with metacognition. Metacognition relates to how a person thinks and the extent to which they understand their own learning and thinking processes. Additionally links between critical thinking and intrinsic motivation are evident based on affective characteristics necessary for demonstration of each.

Statement of the Problem

Based on the interrelationship between critical thinking and intrinsic motivation, and the current realities of secondary education, it is hypothesized that critical thinking instruction explicitly addressing science content can improve student critical thinking ability, and subsequently their motivation to learn science content. The general issue under investigation can be stated as follows: What impact does critical thinking instruction have on student motivation to learn science?

The nature of the research problem allows for investigation of four "component issues" that the research was intended to investigate, including questions related to design of critical thinking instruction and differences in intrinsic motivation based on student populations. The four "component issues" are:

1. What impact does explicit critical thinking instruction using science content have on overall critical thinking ability?
2. To what degree does critical thinking instruction influence student intrinsic motivation to learn science?
3. What impact does critical thinking instruction have on student intrinsic motivation to learn science related to gender?
4. What impact does critical thinking instruction have on students with low intrinsic motivation to learn science?

Importance of the Research

Information gleaned from this research can have broad implications. Aside from expanding the research base in general by providing additional or new information about the nature of critical thinking and intrinsic motivation to learn, this research also has specific implications in a variety of areas. It will provide evidence to support decisions about development of secondary science curriculum and implications for instruction. This research will also yield information regarding improvement of student intrinsic academic motivation to learn science. Finally this research will suggest areas for future research pertaining to the topics of critical thinking and student academic intrinsic motivation. Findings could potentially result in changes in science curriculum, changes in the way curriculum is presented to students, and suggest specific strategies for the improvement of low student academic intrinsic motivation.

Conceptual Definitions

The nature of this research is grounded in connecting two important constructs: (1) critical thinking skills, and (2) academic motivation to learn. Each must be clearly presented for them to be identified and assessed. The following two conceptual definitions are offered the basis for operational definitions in this research:

1. Critical thinking skills are skills that apply basic logic and reason to issues in an attempt to seek out reliable evidence, or to assess the value of presented evidence so as to make the best decision possible.
2. Academic intrinsic motivation is a desire to engage in learning academic content that originates from within a learner, display of which is not dependent upon extrinsic rewards.

These two conceptual definitions are presented to provide conceptual "compass points". They are intended to set the tone for discussion of these constructs and to facilitate scrutiny of the research.

Outline

Chapter two will present relevant research literature associated with the concept of critical thinking. It will also present literature that investigates the nature of intrinsic motivation. The purpose of the review of literature is to provide a theoretical framework for this research that is supported by theoretical and empirical evidence, and will establish a link between critical thinking skills and intrinsic motivation.

Chapter three is an in-depth look at the research methodology. It will provide information pertaining to the research design, data collection, and data analysis. It will explain the selection of variables and assessment tools, and describe development of the intervention. Operational definitions of critical thinking and academic intrinsic motivation will be provided, and limitations of the methodology will be presented.

The results of the research will be discussed in Chapter 4. It will include statistical analysis and findings with regard to research sub-problems. Results will be explained with respect to statistical significance as set forth in chapter 3. Findings presented in Chapter 3 will provide a context for discussion of conclusions.

Chapter 5 will deal with assessing the importance of the research findings. It will delineate areas for further research regarding the research topic. It will present discussion regarding the limitations of the research. Chapter 5 will conclude with the implications this research has for future educational practice.

REVIEW OF LITERATURE

Overview

This chapter is intended to provide an in-depth look at academic literature related to the constructs of critical thinking and intrinsic motivation. The initial section provides a context for adopting an operational definition of critical thinking and for selecting assessment tools. This section is followed by review of literature associated with critical thinking instruction. Analysis of literature pertaining to intrinsic motivation is presented to provide a context for the adoption of an operational definition of academic intrinsic motivation and for selection of assessment tools. A theoretical framework for this research will be established by connecting the constructs of critical thinking and intrinsic motivation through theoretical and empirical evidence reported in the literature. The literature review presented here will be shown to be in support of the research purpose.

Critical Thinking as a Construct

Success in science requires that a student be able to apply rules and criteria, make judgments between examples and non-examples, and make inferences based on criteria (Bailin, 2002). The ability to construct and apply appropriate criteria when making distinctions is essential to critical thinking (Beyer, 1995). Success in science requires such critical thinking skills as students work to make decisions regarding experimental design, data analysis, and categorization (Bailin, 2002). Therefore, science educators should be clear and explicit about teaching critical thinking. Importantly, research evidence indicates clear distinctions between critical thinking and other cognitive abilities exist.

Critical thinking is sometimes associated with problem solving, but it is not the same as problem solving (Beyer, 1985). Critical thinking is generally understood to be composed of elements that are distinguishable and can be identified and cultivated. Some elements commonly agreed to make up critical thinking are: dispositions; the ability to support and defend an argument; the ability to change points of view based on evidence; and the ability to apply structure to ideas or concepts (Beyer, 1985, 1995, 1998; Chaffee, 1990; Elder & Paul, 2001a, 2001b). Theorists Robert Ennis (1962) envisions critical thinking as a three dimensional method to for assessing statements that includes twelve distinguishable aspects. Aspects of critical thinking include dimensions of logic, criterion, and pragmatism (Ennis, 1962). More concise definitions of critical thinking reflect the ability to examine the thinking process carefully so as to provide clearer and enhanced understanding (Chaffee, 1990). Beyer (1985) has defined critical thinking as a process of determining the authenticity, accuracy, and worth of information or knowledge claims.

Teaching Critical Thinking

Many educational researchers deem the teaching of thinking to be essential (Costa, 2001), and efforts to provide instruction on critical thinking represent a large portion of the literature surrounding the topic. Competing theories exist surrounding the best methodology for teaching of critical thinking. There is a prevailing view that critical thinking skills are a generalizable set of skills that can be taught independent of discipline specific knowledge and applied broadly to any context (McPeck, 1990). McPeck (1990) suggests on the other hand, that disciplinary content knowledge, when taught properly, will develop these critical thinking skills inherently. He goes on to suggest that emphasis should be placed on mastery of thinking within a discipline base and not on the process of thinking devoid of specific content knowledge. Other theorists maintain similar views.

Ennis (1989) reports on three varying approaches to critical thinking instruction. According to Ennis, critical thinking taught in the absence of subject-specific content is the termed the "general approach." When critical thinking is imbedded within discipline-specific content instruction knowledge it is termed "infusion" or "immersion". He notes that the distinction between "infusion" and "immersion" is based on how critical thinking elements are presented. Ennis (1989) notes that if critical thinking elements are made explicit then the approach is termed "infusion", and if they are not made explicit the approach is termed "immersion". The final method of teaching critical thinking according to Ennis is called the "mixed" approach. This approach involves mixing the general approach with "infusion" or "immersion", and would include subject-specific instruction with a separate strand devoted to instruction of general critical thinking instruction.

There are also those that consider critical thinking to be a level of cognitive ability that may not be attainable by some students. In regards to the teaching of thinking, some bio-psychologists contend that the ability to think at particular levels may be genetically limited (Brandt, 2001). However, it is a belief that teaching thinking may expedite reaching that limit, and in an interview with Ron Brandt, bio-psychologist Robert Sylwester points out that proper thinking should still be taught (Brandt, 2001).

Intrinsic Motivation

Motivation to learn is an important component of learning (Deci & Ryan, 1985). Motivation is typically defined in terms of an internal state of arousal that guides and sustains behavior. In addition psychologists have traditionally categorized motivation into two categories based on "point of origin". Motivation that is cued by elements outside of the person or the activity they are engaged in is commonly referred to as extrinsic motivation. Motivation that is driven by attitudes, beliefs or emotions within a person or resulting from a task is known as intrinsic motivation (Ormrod, 1999; Stipek, 1998; Woolfolk, 1998). Intrinsic motivation may be experienced as a sense of pride, accomplishment, or satisfaction resulting from activities such as painting a picture or solving a puzzle.

Providing extrinsic rewards for performing a task can decrease an individual's intrinsic motivation to perform the same task (Deci, 1975). For example, Harackiewicz (1979) found that high school students who received extrinsic rewards for completing puzzles under varied conditions showed more decreased intrinsic motivation to complete puzzles than did those receiving no rewards. This can have negative effects if those extrinsic rewards are removed. It is expected that teachers will prepare students for the world outside of the classroom, a world in which extrinsic motivators are not guaranteed if even available, therefore teachers should strive to support and enhance students' intrinsic motivation.

Beliefs about the nature of motivation have varied among those rooted in behavioral psychology to those rooted in cognitive and social cognitive psychology (Weiner, 1984). Although there is some agreement as to what intrinsic motivation is, where, why, or how it originates in individuals is still uncertain (Gottfried, et al, 2001). In an attempt to better understand the elements and influences of intrinsic motivation, various theories have been developed, such as: competency theory, achievement theory, locus of control theory, attribution theory, self-worth theory, and expectancy X values theory (Ormrod, 1999; Stipek, 1998; Woolfolk, 1998). The many theories describing intrinsic motivation illustrate the fact that a consistent interpretation of intrinsic motivation has not been established (Gottfried, et al, 2001). Despite the lack of a definitive and comprehensive understanding of intrinsic motivation, the research evidence indicates that commonalities exist between theories (Gottfried, et al, 2001; Ormrod, 1999; Stipek, 1998). Examples of some commonalities include: inquisitiveness and novelty; recognizing, accepting, and meeting a challenge; and measured personal autonomy (Cordova & Lepper, 1996).

As research on motivation progressed from behavioral theories toward social cognitive theory, emphasis on context and emotion became more prominent. Weiner (1990) noted that motivation depends a great deal on the setting or environment, and self-perceptions of the individual. This idea reflects the commonalties among theories, and the attempts by theorists to design a model that explains learner motivation. Keller established a model that incorporates 4 main focus areas: attention, relevance, confidence, and satisfaction (ARCS), described in Gagné & Driscoll (1988). Gagné and Driscoll (1988) analyzed the four components of the ARCS model. They noted that **attention** means gaining and maintaining student interest through stimulation. According to Gagné and Driscoll (1988), **relevance** is understood to mean that the learner must be aware of the importance and personal benefit of the specific learning in question. They explained learner **confidence** as a conviction on the part of the learner that they can accomplish the given learning task. Gagné and Driscoll described **satisfaction**, the final component of the ARCS model, as a positive feeling on the part of the learner that serves as reinforcement. In terms of intrinsic motivation, this feeling would exist without the presence of external rewards and would serve as a reward in itself.

Connecting Critical Thinking and Intrinsic Motivation

The links between critical thinking and intrinsic motivation are not obvious though the literature suggests some interrelationships. Despite these indications, little research into the nature and extent of the relationship between these constructs exists (Garcia & Pintrich, 1992). One theoretical connection between critical thinking and intrinsic motivation involves the presence of metacognitive and affective aspects in both constructs.

Metacognition is having knowledge of one's own learning, one's own mental processes associated with learning, and how to develop that learning (Ormrod, 1999). Gagné and Driscoll (1988) used a taxonomical approach to categorize learning, which includes both critical thinking and metacognitive abilities. Higher order rule learning is an intellectual skill that requires a learner to select and apply multiple rules to identify solutions to problems (Gagné & Driscoll, 1988). Beyer (1995) indicates that similar abilities such as having knowledge of rules and knowing how to create and apply them are essential elements to critical thinking. Cognitive strategies, another component of Gagné model, refer to the learner demonstrating knowledge of their own learning processes. This is closely related to the concept of metacognition. Gagné defines attitude-based learning outcomes as learning that reflects affective tendencies. Since intrinsic motivation is driven by attitudes, beliefs, or emotions within a person (Ormrod, 1999; Stipek, 1998; Woolfolk, 1998), intrinsic motivation as it relates to academics involves a person being aware of what activities they enjoy or derive satisfaction from, and involving one's self in those things. Hence, metacognitive processes are crucial to intrinsic motivation in an academic context. Based on metacognitive aspects, a theoretical association exists between critical thinking and intrinsic motivation.

Furthermore, critical thinking and intrinsic motivation have affective features. The demonstration of critical thinking appears to be contingent upon a particular person's disposition, among other factors (Beyer, 1995; Perkins et al, 2000, Leader & Middleton 1999). According to Perkins et al (2000), having an appropriate disposition requires the ability to succeed and the desire to do the task. Desire reflects an affective connection to the task and implies that the individual feels that performing the task is of some value. Display of intrinsic motivation often reflects the feelings and emotions found within a person (Ormrod, 1999). As with critical thinking, demonstration of intrinsic motivation involves affective properties. Critical thinking and intrinsic motivation are theoretically associated by the presence of affective components.

The metacognitive and affective attributes displayed by a student help to define his or her perception of their own ability. Perception of ability plays a major role in the demonstration of intrinsic motivation and is in part based on an individual's perceived expectation for the outcome of the task (Stipek, 1984; 1998). If a child believes that the task cannot be accomplished, or that they lack the ability to perform the task, they are less likely to engage in the task (Stipek, 1998). Conversely, students who perceive themselves to be proficient at a particular task are more likely to engage in that task. Pajares (2001) showed that optimistic perceptions held by students were related to higher intrinsic motivation.

The degree of intrinsic motivation may well be related to perceptions about critical thinking. Garcia and Pintrich (1992) explored provided evidence of a relationship between intrinsic motivation and critical thinking ability. Their research revealed positive relationships between metacognitive self-regulatory strategies and critical thinking, as well as positive relationships between intrinsic motivation and critical thinking.

With regard to demonstration of intrinsic motivation, it is important that intrinsic motivation be related to a specific outcome and that measurements of motivation take into account all aspects of an individual (Weiner, 1990). Performance in science is one such outcome and, in that context, gender is a relevant individual aspect. Research done by Weinburgh (1995) has shown that males have a more positive outlook on science than females. However, when considering specific fields of science a different pattern of outcomes occur. Females typically respond with a higher positive attitude toward biology than do males, while males respond better to physical sciences. These differences related to specific fields were further supported by research done by Debacker and Nelson (2000). Weinburgh's research reveals a need to further explore the potential effects of gender on attitudes toward science. Since research has shown negative perceptions of competence may decrease intrinsic motivation (Deci & Ryan, 1985), gender could serve as an important factor governing intrinsic motivation in the context of a high school science classroom.

Purpose

Success in a content area such as high school science requires the acquisition of factual knowledge as well as conceptual knowledge. To understand many of the content-related concepts, or to successfully complete assignments and tasks associated with a content area, students must think critically (Bailin, 2002). Additionally, Chaffee (1991) points out that critical thinking is a higher order cognitive skill rarely taught in high school or college despite its necessity for academic work and employment. Many educational researchers deem the teaching of thinking to be essential (Costa, 2001). By teaching students critical thinking skills and assuring their competence with regard to these skills, educators may ultimately alter learner perceptions. Existing evidence suggest that students who cannot think critically are less likely to be intrinsically motivated to do so. In this study critical thinking was assessed using the Watson and Glaser Critical Thinking Assessment-Short From (WGCTA-S) that uses the following definition of critical thinking.

> "Development of the WGCTA was driven by conceptualization of critical thinking as a composite of attitudes, knowledge, and skills. This composite includes: (1) attitudes of inquiry that involve an ability to recognize the existence of problems and an acceptance of the general need for evidence in support of what is asserted to be true; (2) knowledge of the nature of valid inferences, abstractions, and generalizations in which the weight or accuracy of different kinds of evidence are logically determined; and (3) skills in employing and applying the above attitudes and knowledge." (Watson & Glaser, 1994, pg 9).

This definition takes into consideration the elements of critical thinking established in the literature and will be measured by assessment tools typically used by researchers. In addition, this operational definition is congruent with the level of cognitive ability required to accomplish tasks and integrate concepts as they apply to science classes. Measurement of intrinsic motivation was accomplished using the Children's Academic Intrinsic Motivation Inventory (CAIMI) that offers the following definition of academic intrinsic motivation.

> "The construct of academic intrinsic motivation is defined as enjoyment of school learning characterized by an orientation toward mastery; curiosity; persistence, task-endogeny; and the learning of challenging, difficult, and novel tasks." (Gottfried, 1985, pg. 1).

This definition takes into account the elements of intrinsic motivation evidenced in the research and effectively applies it to an academic context. Though knowledge of the metacognitive and affective similarities between critical thinking and intrinsic motivation may help teachers improve student ability and alter student perception, the question remains: If a teacher can foster a high level of ability and positive student perception with regard to use of critical thinking skills, will intrinsic motivation to employ those skills follow?

METHODOLOGY

Hypothesis

This research is designed to investigate the impact acquisition of critical thinking skills has on student intrinsic motivation to learn science. The literature on critical thinking and intrinsic motivation supports the core hypothesis that improved critical thinking ability could enhance student intrinsic motivation to learn science. Therefore, the H_0 for this research would be: increases in critical thinking ability have no significant effect on student intrinsic motivation to learn science.

Experimental Design

The intended purpose of this research was to investigate the influence of critical thinking instruction on student intrinsic motivation to learn science. Based on subject availability, the desire to control the experiment, and the nature of educational research the most appropriate research design was a quasi-experimental design that included the use of convenience samples. The experimental methodology used was a non-randomized control group pretest-post test design. Four intact science classes (A-D) were selected for pre-testing and post-testing. Three classes (A-C) received critical thinking instruction, and the final class (D) received no instruction.

The presence of group D serves as a control intended to improve internal validity of the design. This design addresses threats to internal validity such as effects due to history, maturation, testing, instrumentation, selection bias, and experimental mortality (Campbell & Stanley, 1966).

Quasi-experimental design makes use of intact groups when randomized sampling is not possible. As a result, significant pretest differences between selected intact groups can present a threat to the validity the research. This threat is addressed in this design due to the use pretest assessments. In this experiment the results of the pretest data were used to determine the relative equivalence of the intact groups prior to implementation of the critical thinking instruction. Overall, this design allows for the most appropriate data collection while controlling for major threats to internal validity in this research context.

Independent Variables

Independent variable selection was based directly on the research questions being addressed. Independent variables were chosen so that data pertaining to post test differences in intrinsic motivation to learn science could be attributed to those factors, and therefore would be applicable to educational practice. The independent variables selected for use in this research included: (1) gender; (2) critical thinking instruction; and (3) initial academic intrinsic motivation to learn science.

The choice of gender as in independent variable was derived from the review of the related literature that indicates intrinsic motivation to learn science content is related to gender. As such, gender was used to investigate the role it might play in any relationship between critical thinking and intrinsic motivation to learn science content.

Critical thinking instruction is the central independent variable differentiating the experimental groups from the control group; therefore, students in the experimental groups were given instruction on critical thinking. Creating experimental groups with regard to this variable was based on three intact experimental groups receiving critical thinking skills instruction. Ultimately, experimental groups were based on number of days of instruction. For each class, two groups were formed. Those receiving full instruction were grouped separately from non-full instruction groups (absent one day). A total of 7 groups were formed, six experimental groups, and one control group that received no critical thinking instruction.

Post-hoc groupings of students were used to create motivational rankings. These rankings were created to address the fourth research question. Pre-test intrinsic motivation scores were used to create a categorical independent variable referred to as motivational rank (MRank). Students scoring lower than one standard deviation (SD) from the pre-test mean were identified as having low intrinsic motivation (Mrank=1). Students scoring within one SD of the pre-test mean were considered to have medium intrinsic motivation (Mrank=2), and students that scored higher than one SD from the pre-test mean were considered to be highly intrinsically motivated (Mrank=3). These categories were selected to determine what difference critical thinking instruction may have had on each of these groups.

Dependent Variables

Dependent variables were selected to make inferences about the effectiveness of the critical thinking instruction and intrinsic motivation to learn science. The two dependent variables selected in this investigation were: (1) post-test critical thinking scores; and (2) post-test intrinsic motivation. These two dependent variables were measured using the Watson-Glaser Critical Thinking Assessment-Short Form (WGCTA-S), and the Children's Academic Intrinsic Motivation Inventory (CAIMI) respectively.

Post-test critical thinking scores were chosen as a dependent variable based on the necessity to assess the acquisition of critical thinking skills. If students failed to make noticeable gains in critical thinking ability, then it would of not be possible to attribute increases in student intrinsic motivation the gaining critical thinking ability.

Following instruction on critical thinking, students were given a post-test on academic intrinsic motivation. The post-test intrinsic motivation scores were selected as the primary dependent variable in this study. Changes in student intrinsic motivation as a result of improved critical thinking ability is at the core of the experimental hypothesis, and as such selection as a dependent variable is essential.

Subjects

Subjects selected for participation in this research were sixty-three southeastern North Carolina high school earth environmental science students. Four classes were selected on the basis of availability, and following consent by the school administrator. Participation in the research project was entirely voluntary, and all participants were required to sign consent forms. Those participants under the age of eighteen likewise had to have the consent of their parent or guardian in order to participate. Participants were also allowed to remove themselves from the research at anytime without consequences.

The four classes included 29 male, and 34 female students. Student mean age was 14.5 years and ranged from 13 to 18 years. Participants included students in grades 9, 10, 11, and 12. The four classes involved in the research provided a sample population that represented each of the school's four periods. Class times began at 8:00 am, 10:35 am, 12:30 pm, and 2:05 pm.

Earth environmental science is a basic course requirement and is not currently subject to state end-of-course examinations. It is often taken by students as freshman or sophomores, and is typically the first science course students take at the high school level. Because it is not subject to state end-of-course examinations, earth environmental science was the most appropriate science course to select for participation in the research due to limited impact on teacher and student accountability. There was no pressure on the participating classroom teachers or the students with regard to preparation for a state standardized test and it thereby possible to intervene with the critical thinking instruction.

Instrumentation

Watson Glaser Critical Thinking Assessment-Short Form (WGCTA-S)

Student critical thinking was assessed prior to and immediately following instruction on critical thinking skills. It is a forty-question assessment that includes questions in five different areas of critical thinking including inference, recognition of assumptions, deduction, interpretation, and evaluation of arguments. The content of this assessment tool is highly related to the content of the critical thinking instruction developed for the research, and is therefore a valid test for use with the instruction given. It is a shortened form of the Watson-Glaser Critical Thinking Assessment and its validity and reliability have been reported in various settings including both individual and group administration (Watson & Glaser, 1994). Although this assessment was designed for use with post-secondary students and for pre-employment assessment, it has been used effectively with high school students (Watson & Glaser 1994). Additionally, according to Watson & Glaser (1994), readability testing placed the tool at a ninth grade reading level making it acceptable for use with all high school students.

Validity of the WGCTA-S is reported according to content, criterion, and construct related validity. Content related validity refers to the degree to which the test measures the intended instructional outcomes with regard to content. It involves a measure of judgment, and the WGCTA-S was selected because it was highly compatible with intended instructional outcomes of the critical thinking instruction.

Criterion related validity is a measure that indicates the degree of correlation between scores on the test measure and some related external criteria. Achievement in science was not a focus of this research; therefore criterion related validity was not established. However, according to Watson and Glaser (1994) the reported correlations between the WGCTA and success in academic areas were significant. In academic areas most related to science (nursing school GPA), significant correlations ($p<0.5$) were reported at 0.30. Additionally, correlations between first semesters GPA at a southern university were 0.30.

Construct validity is a measure of the extent to which an assessment tool is correlated with other measures of the same or similar theoretical construct. With regard to other measures of critical thinking the WGCTA correlates highly. Watson and Glaser (1994) report a correlation between ninth graders taking the WGCTA and the California Test of Mental Maturity of 0.68. In another sample of ninth graders, the correlation between the WGCTA and the Otis-Lennon Mental Ability Test-Form K was 0.70.

Watson and Glaser (1994) also reported the reliability of this measure. For the WGCTA-S the alpha coefficient of internal consistency was 0.81 ($p<0.001$). Moderately low internal consistency findings indicate that the short form subscale scores should not be used independent of the entire measure. Test-retest reliability was reported with a correlation of 0.81 ($p<0.001$).

Children’s Academic Intrinsic Motivation Inventory (CAIMI).

The CAIMI was used to assess intrinsic motivation in science. It is a 44 question self-report inventory that includes 122 responses across five different subject areas. Intrinsic motivation toward four disciplines (reading, math, social studies, and science) as well as intrinsic motivation toward school in general is reported on a five point Likert scale for the first 42 questions. The remaining two questions include a forced choice between intrinsic and extrinsic responses. The instrument incorporates both forward and reverse scored items. Reliability and validity have been established through several studies (Gottfried, 1986).

The CAIMI was selected for two main reasons; appropriateness of use with high school student, and specificity of academic and subject area motivation. The CAIMI was initially developed for use with students in grades four through eight but has been used with high-school students. Also, a high school version of the CAIMI has been developed. The high school version differed from the CAIMI only in the names of two subject areas. The high school version refers to reading and social studies, as English and history respectively. All other aspects of the high-school version are identical to the CAIMI (Gottfried et al, 2001). The high school version has not been adequately reviewed and hence was not chosen. Other measures of intrinsic motivation exist but are not: (1) appropriate for use with high school students; or (2) specific to academic motivation and subject area.

Validity of the CAIMI was assessed largely based on theoretical frameworks surrounding intrinsic motivation. Content validity was established based on the stated operational definition of academic intrinsic motivation. According to Gottfried (1986) the stated operational definition of academic intrinsic motivation was used to guide test development and test items indicate the relationship between the two. Criterion related validity was achieved by establishing correlations between CAIMI subscale scores and student achievement test scores in the same areas. Gottfried (1986) indicates, significant correlations were found in all subject areas except social studies ranging with correlations ranging from 0.24 to 0.44 ($p<0.001$). Additional validity was established by investigating correlations between the CAIMI and scores on Harter's Scale of Intrinsic Versus Extrinsic Orientation in the Classroom. Science correlations were significant at 0.38 ($p<0.001$).

Gottfried (1986) reports test reliability measures of internal consistency and test-retest. Coefficient alphas for the subscales of science were 0.90 and 0.91 in two separate studies indicating subscales were appropriate independent measures. Test-retest studies conducted two months apart indicated stability in two separate studies. The first study reported ranges of coefficients from 0.66 to 0.76, and 0.69 to 0.75 in the second study ($p<0.01$).

Procedures

The treatment extended across 7 days. Two days were used for pre and post testing, and 5 days of critical thinking instruction. Pretest assessments were completed in one day with the students taking the WGCTA-S first, followed immediately by administration of the CAIMI. Both assessments were administered to each class as a whole group. Care was taken to provide strict testing conditions in all four classes. The researcher administered the test in each case following the instructions found in the testing manuals. Pre-testing was completed on Friday and critical thinking instruction began the following Monday. Each experimental group was given instruction on critical thinking skills for 90 minutes each of the next five days. Post-testing was completed on the following Monday.

Critical thinking instruction was provided to the three experimental groups by the researcher. In the case of the experimental groups the regular classroom teacher did remain in the room but did not participate in delivery of instruction during the week. The control group continued to receive scheduled science instruction based in the school curriculum from their regular teacher.

Critical thinking instruction was designed by the researcher and based in ninth grade earth environmental science content. The critical thinking content was derived from the theoretical constructs established in the literature review and adapted from the curriculum used in a university level critical thinking course (Fawkes, 1991). The university course content and material was used as a general guide for sequencing and establishing content framework, yet the core instruction involved the application of ninth grade science concepts.

The learning experiences involved a variety of instructional methods, such as lecture, inquiry, cooperative groups, and independent work. The critical thinking instruction was divided into five modules: (1) basic logic; (2) argument structure; (3) inductive and deductive thinking; (4) argument evaluation; and (5) making arguments. A brief review of the contents of each module is described below:

1. Basic logic-four kinds of knowledge
    a. Declarative Knowledge (Verbal associations)
    b. Concepts
    c. Rules and rule relationships
    d. Cognitive strategies
2. Argument structure

    a. Issue
    b. Premise (primary and secondary)
    c. Conclusion or claim (primary and secondary)
3. Deduction and Induction
    a. Deductive thinking
        i. Characteristics
        ii. Examples
    b. Inductive thinking
        i. Characteristics
        ii. Examples
4. Argument evaluation
    a. Reflective questioning
    b. Validity
    c. Soundness
    d. Correctness
    e. Fallacies
5. Making arguments
    a. Evaluate the evidence
    b. Consider all the possibilities
    c. Fact versus opinion
    d. Knowledge versus belief
    e. Accounting for prejudice and emotion
    f. Predicting and evaluating consequences

During each segment, all critical thinking components were demonstrated through familiar and unfamiliar earth/environmental science content such as oceanography and astronomy. The critical thinking instruction culminated with the students analyzing an issue of local importance about the use of seawalls to protect private property. Students were asked to read about the decision made by the local community, and asked to make their own argument regarding the correctness or incorrectness of the decision.

Each module began with a review of the previous days assignment followed by guided notes and discussion lasting between 30 and 40 minutes. Following the discussion or lecture section, students were asked to complete assignments that illustrating the main points addressed in the notes and discussion. Assessment of student progress was accomplished by evaluating individual student work, paper based group assessment, and group presentations. Each day closure was achieved through connecting the days content to the content from the previous day. Sample lesson plans can be seen in the Appendix.

Analysis

Statistical analysis of the data was accomplished using SPSS© version 11.5. Each subject's data was coded with an identification code to protect participant's privacy, and names were not included within the data set. Every student response was entered in the database with the exception of responses that were incomplete, improperly answered, or missing entirely. When student responses were incomplete, improperly answered, or missing the data was excluded from the data set. All other data including demographic information was included for analysis.

The experimental design assumes pretest differences among groups. These differences present a possible threat to the validity of the data collection. In order to establish that pretest differences were not significant ($p \leq 0.05$) one-way ANOVA analysis was used. ANOVA's were conducted with regard to differences in pretest critical thinking skill and intrinsic motivation based on gender, and pretest intrinsic motivation to learn science.

Post-test data was analyzed to reveal changes in critical thinking ability, changes in intrinsic motivation to learn science. This analysis included the use of descriptive statistics and paired-t-tests. Pair-t-tests of pretest post-test differences in dependent variables were considered significant at $p \leq 0.10$. The exploratory nature of this research included elements that made this p value appropriate. The research design made use of a brief period of critical thinking instruction. Additionally the relatively low numbers of participants (N=63) further supports statistically important findings at $p \leq 0.10$.

FINDINGS

Pretest Analysis

Pretest analyses were conducted to investigate the potential for statistically significant pretest differences between groups based on independent variables. Statistical significance for pretest analyses was set at $p \leq 0.05$. Pretest data included scores for the Watson-Glaser Critical Thinking Appraisal-Short form (WGCTA-S) used to assess critical thinking skills, and the Children's Academic Intrinsic Motivation Inventory (CAIMI) used to assess intrinsic motivation to learn science. One-way analyses of variance (ANOVA) were used with post-hoc t-tests.

ANOVAs were based on mean scores for each independent variable. The frequency distributions for the WGCTA-S pre-test are reported in Table 1. The mode for

Table1.

WGCTA-S Pretest Frequency Distributions by Group

Scores	Group							Total
	1	2	3	4	5	6	7	
13	1	0	0	1	0	0	0	2
14	0	0	0	1	0	0	0	1
15	1	0	0	0	1	1	0	3
17	3	1	0	0	1	0	1	6
18	0	0	0	0	0	0	1	1
19	1	0	2	0	0	0	1	4
20	0	1	2	0	2	2	3	10
21	0	0	1	0	0	1	1	3
22	0	1	2	0	2	0	1	6
23	3	0	0	1	0	2	1	7
24	1	0	2	0	2	0	1	6
25	0	0	2	0	0	0	2	4
26	0	1	1	0	0	0	0	2
27	0	1	1	0	1	0	0	3
30	0	1	0	0	0	0	1	2
31	0	0	0	0	0	0	1	1
32	0	0	0	0	0	0	1	1
34	0	0	0	0	0	1	0	1
Total	10	6	13	3	9	7	15	63

the pre-test distribution was 20. The mean scores for the WGCTA-S by experimental group are reported in Table 2. The highest mean score of 23.67 belonged to experimental group #2. The lowest pretest mean score on the WGCTA-S was 16.67 and belonged to experimental group #4. Mean scores for the WGCTA-S based on gender are reported in Table 3 and shows pretest mean scores for males and females to be 22.62 and 21.03 respectively. Pretest means for the WGCTA-S based on motivational ranks are reported in Table 4. Mrank 1 reported the highest pretest mean score for the WGCTA-S at 22.33. The lowest mean score of 20.88 belonged to Mrank 3.

Table 2.

Pretest Descriptive Statistics for WGCTA-S

Ex. Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	10	19.10	3.900	1.233	13	24
2	6	23.67	4.844	1.978	17	30
3	13	22.62	2.725	.756	19	27
4	3	16.67	5.508	3.180	13	23
5	9	21.22	3.701	1.234	15	27
6	7	22.29	5.823	2.201	15	34
7 [α]	15	23.13	4.719	1.218	17	32
Total	63	21.76	4.475	.564	13	34

[α]Control group received no critical thinking instruction.

ANOVA's for pretest critical thinking ability were conducted for each independent variable grouping and are reported in Table 5. No statistically significant differences between groupings with regard to pretest critical thinking ability resulted ($p \leq 0.05$). This reflects the degree of pre-treatment similarity among groups in their mean levels of critical thinking ability.

Table 3.

Pre-test Descriptive Statistics for WGCTA-S

Gender	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Males	29	22.62	3.427	.636	17	31
Females	34	21.03	5.143	.882	13	34
Total	63	21.76	4.475	.564	13	34

Table 4.

Pre-test Descriptive Statistics for WGCTA-S

Mrank	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	18	22.33	4.753	1.120	14	32
2	29	21.90	4.143	.769	13	31
3	16	20.88	4.884	1.221	13	34
Total	63	21.76	4.475	.564	13	34

Table 5.

Analysis of Variance for Pretest WGCTA-S

Independent Variable	SS	df	MS	F	p
Ex. Group					
Between Groups	212.734	6	35.456	1.930	.092*
Within Groups	1028.694	56	18.370		
Gender					
Between Groups	39.630	1	39.630	2.012	.161*
Within Groups	1201.798	61	19.702		
Mrank					
Between Groups	18.989	2	9.494	.466	.630*
Within Groups	1222.440	60	20.374		
Total	1241.429	62			

Note. Mrank groups created based on pretest motivational differences.
*$p \leq 0.05$.

Pretest data regarding intrinsic motivation to learn science was similarly analyzed for statistically significant differences. Pretest CAIMI science scores were analyzed with one-way analyses of variance (ANOVA) using pretest mean scores. The frequency distribution or the pretest CAIMI science scores are reported in Table 6. The pretest scores reflect a wide distribution with scores of 72, 77, 79, 87, and 105 each occurring 3 times. Table 7 shows pretest mean scores by experimental group for the CAIMI for science. The highest mean found among pretest experimental groups was 94.57 (group 7). Experimental group 4 had the lowest mean pretest score at 72.33. The mean scores for the CAIMI for science based on gender is reported in Table 8. The mean scores for males and females were 84.31 and 89.74 respectively. Mean scores for the CAIMI for science based on motivational rankings are reported in Table 9. Mrank was based on the pretest CAIMI science scores, so pretest means are expectedly lowest for Mrank 1 (67.67) and highest for Mrank 3 (107.75). The mean score for Mrank 2 was 88.07.

Pretest ANOVAs based on CAIMI science scores were conducted on experimental group and gender. ANOVAs were conducted based on Mrank because this grouping was established based on differences in pretest CAIMI science scores and these Mrank groups were expected to be different. Pretest ANOVAs for CAIMI science are reported in Table 10. Statistical significance was again set at $p \leq 0.05$ due to the pretest conditions. The ANOVA results based on pretest CAIMI science scores showed no statistically significance differences among pretest groupings based on experimental group or gender.

Table 6.

CAIMI Science Pretest Frequency Distributions by Group

Score	Group							Totals
	1	2	3	4	5	6	7	
39	1	0	0	0	0	0	0	1
45	1	0	0	0	0	0	0	1
54	0	0	1	0	0	0	0	1
63	0	0	1	0	0	0	0	1
64	0	0	0	1	0	0	0	1
66	0	0	0	1	0	0	0	1
69	0	0	0	0	0	0	1	1
70	0	1	0	0	0	0	0	1
72	0	1	1	0	0	0	1	3
74	0	0	0	0	0	0	1	1
75	1	0	0	0	0	0	0	1
76	0	0	1	0	0	0	1	2
77	0	0	0	0	2	0	1	3
78	0	0	0	0	1	1	0	2
79	0	0	1	0	1	1	0	3
81	0	0	1	0	0	0	0	1
82	0	0	1	0	0	0	0	1
83	0	0	0	0	0	0	2	2
84	0	0	0	0	1	0	1	2
85	0	0	1	0	0	0	0	1
86	1	0	0	0	0	0	0	1
87	0	1	0	1	0	0	1	3
88	0	0	0	0	1	0	0	1
89	0	0	1	0	0	0	0	1
90	0	0	1	0	0	1	0	2
91	0	0	1	0	0	0	0	1
95	1	0	0	0	0	0	0	1
96	0	0	0	0	1	0	0	1
97	0	1	0	0	0	0	0	1
98	0	0	0	0	0	0	1	1
99	0	1	0	0	0	1	0	2
100	0	0	0	0	0	0	2	2
101	0	0	0	0	0	0	1	1
102	0	0	0	0	0	1	0	1
104	1	0	0	0	0	0	1	2
105	1	1	0	0	0	1	0	3
106	1	0	0	0	0	0	0	1
109	1	0	0	0	0	1	0	2
111	1	0	1	0	2	0	0	4
115	0	0	1	0	0	0	1	2
Total	10	6	13	3	9	7	15	63

Table 7.

Pretest Descriptive Statistics for the CAIMI for Science

Ex. Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	10	87.50	26.475	8.372	39	111
2	6	88.33	14.638	5.976	70	105
3	13	83.69	16.800	4.659	54	115
4	3	72.33	12.741	7.356	64	87
5	9	89.00	13.928	4.643	77	111
6	7	94.57	12.448	4.705	78	109
7 $^{\alpha}$	15	88.20	13.852	3.577	69	115
Total	63	87.24	16.808	2.118	39	115

$^{\alpha}$ Control group received no critical thinking instruction.

Table 8.

Pretest Descriptive Statistics for the CAIMI for Science

Gender	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Males	29	84.31	15.414	2.862	39	115
Females	34	89.74	17.755	3.045	45	115
Total	63	87.24	16.808	2.118	39	115

Post-test Analysis

Post-test analysis included descriptive statistics and paired-t-tests. Paired-t tests were used to test for statistically significant changes from pre-test to post-test performance. Due to the exploratory nature of this research statistical significance for the post-test analyses was set at $p \leq 0.10$. Frequency distributions and descriptive statistics for the Watson-Glaser Critical Thinking Inventory-Short Form (WGCTA-S) and the Children's Academic Intrinsic Motivation Inventory (CAIMI) for science are reported.

Table 9.

Pretest Descriptive Statistics for the CAIMI for Science

Mrank		N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1							
	Males	7	65.86	14.159	5.352	39	77
	Females	11	68.82	9.368	2.825	45	77
	Total	18	67.67	11.162	2.631	39	77
2							
	Males	19	87.16	7.244	1.662	78	100
	Females	10	89.80	7.285	2.304	79	99
	Total	29	88.07	7.240	1.345	78	100
3							
	Males	3	109.33	6.658	3.844	102	115
	Females	13	107.38	3.927	1.089	101	115
	Total	16	107.75	4.344	1.086	101	115
Total							
	Males	29	84.31	15.414	2.862	39	115
	Females	34	89.74	17.755	3.045	45	115
	Totals	63	87.24	16.808	2.118	39	115

Frequency distributions for post-test WGCTA-S scores are reported in Table 11. The mode for this distribution was 23. Table 12 presents the means for post-test WGCTA-S scores for the 7 experimental groups. Group 6 had the highest mean critical thinking score (24.57). Group 1 had the lowest post-test mean score (21.30).

Table 10

Analysis of Variance for Pretest CAIMI science

Independent Variable	SS	df	MS	F	p
Ex. Group					
Between Groups	1256.045	6	209.341	.721	.634*
Within Groups	16259.384	56	290.346		
Gender					
Between Groups	460.604	1	460.604	1.647	.204*
Within Groups	17054.825	61	279.587		
Mrank					
Between Groups	13646.567	2	6823.283	105.818	.000
Within Groups	3868.862	60	64.481		
Total	17515.429	62			

Note. Mrank groups created based on pretest motivational differences.
*$p \leq 0.05$.

Post-test means for the WGCTA-S based on gender and motivational rank are reported in Table 13 and Table 14, respectively. Post-test means gender were 23.38 for males, and 22.50 for females. The post-test means for the WGCTA-S by motivational rank showed that Mrank 3 (highest 25% by pretest motivation) had the lowest mean score at 21.00. The highest mean score for the post-test belonged to Mrank 2 (middle 50% by pretest motivation) with a mean score of 24.14.

Frequency distribution of post-test CAIMI science scores are reported in Table 15. The mode for this distribution was 92. The experimental groups mean scores for the post-test CAIMI science are reported in Table 16. Group 5 had the highest mean score for the post-test CAIMI science of 93.56. Group 3 had the lowest post-test mean for the CAIMI science at 79.46. The post-test CAMI science data with regard to

Table 11.

WGCTA-S Post-test Frequency Distributions

Score	Group 1	2	3	4	5	6	7	Totals
14	1	0	0	0	0	1	0	2
15	0	0	0	0	0	0	1	1
16	0	0	1	0	0	1	1	3
17	1	1	0	0	0	0	0	2
18	2	0	1	0	1	0	0	4
19	0	1	0	1	1	0	0	3
20	1	1	1	1	1	0	1	6
21	2	0	0	0	1	0	1	4
22	0	0	2	0	1	0	0	3
23	0	1	3	0	1	0	3	8
24	0	0	1	0	1	1	3	6
25	1	0	1	0	0	1	1	4
26	0	0	0	0	0	0	1	1
27	0	0	1	1	1	1	0	4
28	1	0	1	0	1	0	0	3
29	0	1	0	0	0	0	3	4
30	0	1	1	0	0	1	0	3
31	1	0	0	0	0	0	0	1
36	0	0	0	0	0	1	0	1
Total	10	6	13	3	9	7	15	63

gender is reported in Table 17. This table indicates the mean scores for the post-test CAIMI science for males to be 84.14 and females to be 89.94. Post-test CAIMI science means by motivational rank are reported in Table 18. The highest mean score belonged to Mrank 3 (102.56), and the lowest mean score belonged to Mrank 1 (72.00).

WGCTA-S post-test ANOVAs are reported in Table 19. Again, due to the exploratory nature of this research statistical significance set at $p \leq 0.10$. Post-test differences were statistically significant for Mrank groups ($p \leq 0.093$). This indicates changes in critical thinking based on motivational rank. There were no statistically significant differences between experimental groups, or based on gender.

ANOVAs were also conducted based on CAIMI science scores and are reported in Table 20. No statistically significant differences were found between experimental groups or gender. Differences among Mrank groups are indicated, but these groups were different to begin with based on pretest motivational scores.

Dependent sample t-tests were used to assess pre/post-test differences. . The paired-tests for the independent variable groups are reported for the WGCTA-S and the CAIMI science. Table 21 presents the results of paired t-tests for experimental groups. As Table 21 indicates, all groups except 2 and 7 showed positive changes in mean WGCTA-S scores. Of those groups with positive change, groups 1 and 4 were statistically significant positive changes at $p \leq 0.073$ and $p \leq 0.026$, respectively. The gain in mean WGCTA-S scores suggests that critical thinking ability improved from pretest to post-test for all but one of the experimental groups.

Table 22 shows the paired-t test results for changes WGCTA-S by gender. There were statistically significant gains in critical thinking ability among females ($p \leq 0.046$). Although the males showed improvement, the gain was not statistically significant.

Table 12.

Post-test Descriptive Statistics for the WGCTA-S

Ex. Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	10	21.30	5.250	1.660	14	31
2	6	23.00	5.404	2.206	17	30
3	13	23.15	3.870	1.073	16	30
4	3	22.00	4.359	2.517	19	27
5	9	22.44	3.432	1.144	18	28
6	7	24.57	7.656	2.894	14	36
7 [α]	15	23.40	4.205	1.086	15	29
Total	63	22.90	4.683	.590	14	36

[α] Control group received no critical thinking instruction.

Table 13.

Post-test Descriptive Statistics for the WGCTA-S

Gender	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	29	23.38	4.640	.862	15	30
2	34	22.50	4.750	.815	14	36
Total	63	22.90	4.683	.590	14	36

Table 14.

Post-test Descriptive Statistics for the WGCTA-S

Mrank	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	18	22.61	4.500	1.061	16	31
2	29	24.14	4.121	.765	16	30
3	16	21.00	5.391	1.348	14	36
Total	63	22.90	4.683	.590	14	36

Table 23 shows paired-t test of WGCTA-S scores of groups by motivational rank. All three groups showed positive change in the post-test WGCTA-S indicating improved critical thinking. Of the three groups, only Mrank 2 showed statistically significant gains ($p \leq 0.001$) in critical thinking score.

Paired-t test were again used to determine the statistical significance of any changes in mean scores on the CAIMI science from pretest to posttest. Paired-t test were conducted for the CAIMI science with regard to experimental group. These data is reported in Table 24. One of six groups participating in critical thinking instruction reported a statistically significant positive change. Group 4 showed a statistically significant ($p = \leq 0.087$) positive change in motivation to learn science, with the statistical significant level of $p \leq 0.10$. Of the remaining five treatment groups, only three showed positive gains in mean motivational scores from pre-test to post-test.

Table 15.

CAIMI Science Post-test Frequency Distributions

Score	Group							Totals
	1	2	3	4	5	6	7	
38	0	0	0	0	0	1	0	1
43	1	0	0	0	0	0	0	1
52	0	0	1	0	0	0	0	1
57	1	0	0	0	0	0	0	1
59	0	0	1	0	0	0	0	1
60	0	0	1	0	0	0	0	1
62	0	0	1	0	0	0	0	1
63	0	0	1	0	0	0	0	1
73	0	0	0	0	0	0	1	1
74	0	0	1	0	0	0	1	2
75	0	0	1	0	0	0	1	2
77	1	0	0	0	0	0	0	1
78	0	1	0	0	0	0	1	2
79	0	1	0	1	1	0	0	3
80	0	1	0	0	0	1	1	3
81	0	0	0	0	1	0	0	1
82	0	0	0	1	0	0	0	1
83	0	0	0	0	0	1	1	2
84	0	0	0	0	1	0	1	2
86	1	0	0	0	0	0	0	1
87	0	0	1	0	0	0	1	2
88	0	1	1	0	0	0	0	2
90	0	0	0	0	1	0	0	1
91	0	0	0	0	0	0	1	1
92	1	0	1	1	0	0	2	5
94	1	0	1	0	0	0	0	2
95	0	1	0	0	0	0	2	3
97	0	0	0	0	1	0	0	1
98	0	0	0	0	2	0	0	2
99	0	0	0	0	0	1	0	1
104	0	0	0	0	0	1	0	1
105	1	0	0	0	0	0	0	1
106	0	0	0	0	1	0	0	1
108	1	1	0	0	0	1	1	4
109	1	0	0	0	1	0	0	2
111	0	0	0	0	0	1	0	1
113	0	0	1	0	0	0	0	1
114	0	0	1	0	0	0	0	1
119	0	0	0	0	0	0	1	1
122	1	0	0	0	0	0	0	1
Total	10	6	13	3	9	7	15	63

Table 16.

Post-test Descriptive Statistics for the CAIMI-S

Ex. Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1	10	89.30	24.568	7.769	43	122
2	6	88.00	11.781	4.810	78	108
3	13	79.46	20.399	5.658	52	114
4	3	84.33	6.807	3.930	79	92
5	9	93.56	10.713	3.571	79	109
6	7	89.00	25.456	9.621	38	111
7 [α]	15	88.40	12.800	3.305	73	119
Total	63	87.27	17.767	2.238	38	122

[α] Control group received no critical thinking instruction.

Table 17.

Post-test Descriptive Statistics for the CAIMI science

Gender	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
Males	29	84.14	17.046	3.165	38	119
Females	34	89.94	18.181	3.118	52	122
Total	63	87.27	17.767	2.238	38	122

The paired-t tests of CAIMI science scores based on gender showed similar innocuous results. The paired-t tests based on gender are reported in Table 19. The data indicates that only the females showed a gain in intrinsic motivation to learn science, but it was not statistically significant. The males did not show a positive change in intrinsic motivation to learn science.

Post-test CAIMI science data was most revealing with regard to the independent variable of motivational rank. Paired-t test of CAIMI science scores are reported in

Table 18.

Post-test Descriptive Statistics for the CAIMI science

Mrank	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
1						
Males	7	74.57	18.338	6.931	43	98
Females	11	70.36	10.576	3.189	52	82
Total	18	72.00	13.746	3.240	43	98
2						
Males	19	86.95	8.708	1.998	74	108
Females	10	90.90	12.087	3.822	63	106
Total	29	88.31	9.968	1.851	63	108
3						
Males	3	88.67	44.163	25.497	38	119
Females	13	105.77	9.094	2.522	92	122
Total	16	102.56	19.332	4.833	38	122
Total						
Males	29	84.14	17.046	3.165	38	119
Females	34	89.94	18.181	3.118	52	122
Totals	63	87.27	17.767	2.238	38	122

Table 20. Findings here indicate positive change in mean CAIMI science scores for those students who were least motivated based on pre-test data. Mrank 1 showed a gain in mean CAIMI science score of 4.33 from pre-test to post-test. The paired-t test indicated that this change was statistically significant at $p=0.099$. Additional findings with regard to motivational rank were that the group established by the CAIMI pretest to

Table 19.

Analysis of Variance for the Post-test WGCTA-S.

Independent Variable	SS	df	MS	F	p
Ex. Group					
Between Groups	54.100	6	9.017	.387	.884
Within Groups	1305.329	56	23.309		
Gender					
Between Groups	12.101	1	12.101	.548	.462
Within Groups	1347.328	61	22.087		
Mrank					
Between Groups	103.703	2	51.851	2.478	.093*
Within Groups	1255.726	60	20.929		
Total	1359.429	62			

Note. Mrank groups created based on pretest motivational differences.
*$p \leq 0.10$.

be the most motivated actually showed a decrease in mean intrinsic motivation to learn science. Mrank 3 showed a change in mean score or –5.19. Paired-t test of this change revealed that it was not statistically significant. Those students identified as Mrank 2 showed little gain in mean CAIMI science score.

Table 20.

Analysis of Variance for Post-test CAIMI Science

Independent Variable	SS	df	MS	F	p
Ex. Group					
Between Groups	1258.593	6	209.766	.641	.697
Within Groups	18311.820	56	326.997		
Gender					
Between Groups	527.082	1	527.082	1.688	.199
Within Groups	19043.331	61	312.186		
Mrank					
Between Groups	7970.268	2	3985.134	20.613	.000
Within Groups	11600.144	60	193.336		
Total	19570.413	62			

Note. Mrank groups created based on pretest motivational differences.
*p≤0.10.

Table 21.

Paired-t Test for the WGCTA-S

Ex. Group	Mean Difference	Std. Deviation	Std. Error Mean	t	df	p
1	-2.20	3.425	1.083	-2.031	9	.073*
2	.67	6.377	2.603	.256	5	.808
3	-.54	3.886	1.078	-.500	12	.626
4	-5.33	1.528	.882	-6.047	2	.026*
5	-1.22	3.930	1.310	-.933	8	.378
6	-2.29	4.152	1.569	-1.457	6	.195
7^{α}	-.27	4.350	1.123	-.237	14	.816

Note. Negative mean differences indicate positive change from pre-test to post-test.
$^{\alpha}$ Control group received no critical thinking instruction.
*p≤0.10.

Table 22.

Paired-t Test for WGCTA-S

Gender	Mean Difference	Std. Deviation	Std. Error Mean	t	df	p
Males	-.76	4.315	.801	-.947	28	.352
Females	-1.47	4.143	.711	-2.070	33	.046*

Note. Negative mean differencesindicate positive change from pre-test to post-test.
*p≤0.10.

Table 23.

Paired-t Test for WGCTA-S

Mrank	Mean Difference	Std. Deviation	Std. Error Mean	t	df	p
1	-.28	5.334	1.257	-.221	17	.828
2	-2.24	3.324	.617	-3.632	28	.001*
3	-.13	3.981	.995	-.126	15	.902

Note. Negative mean differences indicate positive change from pre-test to post-test.
*p≤0.10.

Table 24.

Paired-t Test for CAIMI science

Ex. Group	Mean Difference	Std. Deviation	Std. Error Mean	t	df	p
1	-1.80	8.297	2.624	-.686	9	.510
2	.33	13.952	5.696	.059	5	.956
3	4.23	9.221	2.557	1.654	12	.124
4	-12.00	6.557	3.786	-3.170	2	.087*
5	-4.56	10.806	3.602	-1.265	8	.242
6	5.57	25.877	9.781	.570	6	.590
7 $^{\alpha}$	-.20	6.132	1.583	-.126	14	.901

Note. Negative mean differences indicate positive change from pre-test to post-test.
$^{\alpha}$ Control group received no critical thinking instruction.
*p≤0.10.

Table 25.

Paired-t Test for CAIMI science

Gender	Mean Difference	Std. Deviation	Std. Error Mean	t	df	p
Males	.17	15.095	2.803	.062	28	.951
Females	-.21	9.370	1.607	-.128	33	.899

Note. Negative mean differences indicate positive change from pre-test to post-test. *p≤0.10.

Table 26.

Paired-t Test for CAIMI science

Mrank	Mean Difference	Std. Deviation	Std. Error Mean	t	df	p
1	-4.33	10.538	2.484	-1.745	17	.099*
2	-.24	8.588	1.595	-.151	28	.881
3	5.19	17.429	4.357	1.191	15	.252

Note. Negative mean differences indicate positive change from pre-test to post-test. *p≤0.10.

CONCLUSIONS

Summary

Secondary education presents a multitude of challenges for the classroom teacher. Not least of which is motivating students. Every secondary teacher strives to develop student motivation to learn. Research literature indicates that critical thinking may well serve to improve student intrinsic motivation to learn. Relationships exist among the characteristics of intrinsic motivation and critical thinking. The current research was developed in order to better understand the nature and extent of these relationships. Students were evaluated on critical thinking ability and intrinsic motivation before and after critical thinking instruction using science content as a medium. Data regarding any changes in student critical thinking and intrinsic motivation were analyzed to investigate significant findings. The conclusions will be based on the four research questions established for this research.

1.) What impact does critical thinking instruction using science content have on overall critical thinking ability?

2.) To what degree does critical thinking instruction influence student motivation to learn science?

3.) What impact does critical thinking instruction have on differences in motivation related to gender?

4.) What impact does critical thinking instruction have on students with low intrinsic motivation?

Question 1

Question one is a question that specifically relates to instructional practice and the merger of critical thinking skills with science content. With increased emphasis on student's thinking processes by local, state, and federal curriculum developers, it is an important question to investigate. Findings from the current research showed that five of the six treatment groups showed positive change in critical thinking ability post treatment. Two of these groups showed statistically significant gains (see Table 21). These results indicate that improvement in critical thinking can be accomplished by using a curriculum approach that centers on critical thinking instruction. Critical thinking skills are distinguishable and teachable, providing that the curriculum effectively addresses these skills. They must be identified during planning of instruction, incorporated into lesson delivery, and strengthened by practice. The limited statistical significance shown in the post-test differences in critical thinking may be attributed to the brevity of critical thinking instruction, and the depth of the material covered. Still, with five of six treatment groups showing improved critical thinking skills, this research supports the belief that teaching critical thinking via a clear and explicit approach can yield improved critical thinking skills. One suggestion for future research into this question includes creating a lengthier instructional period that lessens the amount of critical thinking material covered per instructional unit. A further implication for future research includes an in-depth investigation into the nature of science curriculum. Curriculum should be reviewed to determine how critical thinking skills instruction is included and what definition of critical thinking the curriculum it utilizes. Finally given the possibility of improved critical thinking ability as a result of instruction using science content, it would be of importance to then investigate the degree of science content acquisition. In other words, it would be important to measure the gains in critical thinking against science achievement.

Question 2

Improvement of student intrinsic motivation to learn science is of importance to classroom science teachers. Investigation into ways of accomplishing this task has merit on two levels. It can make teaching more rewarding for the educator by decreasing the amount of effort expended trying to motivate students. Additionally, it can improve the opportunities for student learning by increasing levels of involvement and interest. The second research question investigates the degree to which critical thinking instruction can improve student motivation to learn science in science students as a whole. The results of this research present mixed findings with regard to this question. Only three of the six treatment groups showed positive changes in motivation to learn science. Of those three, one was found to be statistically significant (see Table 24). These findings indicate that with certain experimental groups the instruction proved to increase motivation, while with others, it had an opposite effect. It can be concluded that with regard to students in general there were only minor benefits to intrinsic motivation. Again this could be due to the brief nature of the instructional period or possible to the large amount of information covered during the instructional period. Research regarding this question could be expanded to included broader numbers of students. Improved sample sizes would improve statistical power of the research. Another variation of additional research could include research on intrinsic motivation in relation to different scientific disciplines.

Impact of critical thinking instruction may have greater impact on intrinsic motivation dependent upon scientific discipline.

Question 3

The third question deals with a specific population of students. Question 3 attempts to provide information about the motivational differences between genders as a function of critical thinking instruction. Finding pertaining to this question reveals some interesting findings. Females showed statistically significant post-test gains in critical thinking ability (see Table 22). This gain however did not reflect any statistically significant changes in motivation to learn science content, although they did report a positive change in mean intrinsic motivation to learn science content (see Table 25). The findings show that female intrinsic motivation to learn science improved following a statistically significant increase in critical thinking ability. However, the degree of improvement in intrinsic motivation to learn science was small. It can be concluded that there is evidence that would support additional research into this question. This research should include greater numbers of participants with regard to motivational levels. Also research should include qualitative data collection from teachers and students. Future research could include teacher identified low intrinsically motivated students, or students could identify themselves as low, medium, or highly motivated prior to critical thinking instruction. This would add a valuable qualitative component to the nature investigations.

Question 4

Question 4 is perhaps the most important question addressed by this research. It deals with the improvement of student intrinsic motivation to learn science among those students identified as having low intrinsic motivation. These students are the students that often require the most effort on the part of the teacher to get them to participate, are the most likely to become disengaged, and to the most likely to perform poorly. When considering those students in the lowest quartile with regard to intrinsic motivation to learn science, we can see some interesting and promising results. All three Mrank groups based on pre-test motivational scores showed positive changes in their critical thinking means scores (see Table 23). Of these three, Mrank 2 showed statistically significant gains. Based on this we can conclude that all three groups showed varying degrees of critical thinking improvement. The corresponding post-test motivational findings were additionally interesting. Of the three Mrank groups, the lowest intrinsically motivated students (Mrank 1) showed statistically significant gains in intrinsic motivation to learn science (see Table 26). This finding supports the hypothesis that critical thinking instruction resulting in improved critical thinking ability can lead to improved intrinsic motivation to learn science among those students that are identified as poorly motivated. An additional finding with regard to question 4 is the resulting post-test motivation of the other two Mrank populations. Post-test motivation with regard to Mrank 2 remained fairly steady showing only a minimal gain in post-test motivational mean scores. Interestingly, the highest motivated students (Mrank 3) reported a decrease in intrinsic motivation to learn science post-test. This evidence promotes the existence of an interrelationship between critical thinking and intrinsic motivation, and future research should explore these findings in an attempt to further investigate the impact improved critical thinking ability may have on students with varying levels of motivation to learn science content. This could include broader groups of students separating them into more stratified motivational groups. Further research into motivational impacts of critical thinking instruction could be conducted on various different samples of low motivated students to investigate the degree to which the current findings may be generalized to larger and more diversified groups of low motivated students.

Limitations

The experimental design selected for this research includes limitations based on subject selection. Because intact groups were used instead of randomized samples, groups have their own individual characteristics that make them different from other groups. The degree to which these groups differ in regard to dependent variables can be addressed and accounted for to a degree, but ultimately not overcome. Additionally, selection of the participants was based on subject availability, which served to limit the number of participant resulting in small sample sizes. This was however an appropriate size given the exploratory nature of the research. The research was a broad approach intended to provide a variety of information regarding the research questions. Findings support with varying degrees, the continuation of research with regard to all questions.

Critical thinking is often taught for entire semesters at the post-secondary level, and the content addressed in such a course was condensed in order to be delivered in a cursory one-week period. Essential elements were addressed, but a wealth of additional critical thinking instruction was left out. It was the intent that the instructional treatment teach critical thinking skills using science content as a medium. As such the instructional materials and design of the critical thinking instruction had not previously been tested for its effectiveness. As a result, the critical thinking instruction itself is a limitation of the experiment due to its brevity, and originality.

The class groups used in this research were classes that interacted closely. Students attended the class in the same classroom and had the same teacher. This actuality leads to the possibility for crossover effects from sample group to sample group. The use of a control group served to limit this to a degree but could not prevent student interaction outside of the classroom altogether. Improvements in this area could be achieved by conducting future research in a variety of schools where potential crossover would be removed.

Curriculum Implications

Implications this research has with regard to science curriculum are substantial. This research indicates that critical thinking components are lacking in current science curriculum, and opportunities for critical thinking instruction are left to the classroom teacher to address or not address. The instructional approach used to design most science curriculum materials imply that critical thinking skills are a component but they are not adequately addressed. As such, responsibility for development of critical thinking skills instruction falls mainly on the classroom teacher, and is dependent to a degree on their expertise with regard to instructional design.

The research shows that, although challenging to develop, critical thinking can be addressed effectively through the use of science content. Using science content to meet critical thinking objectives allows for educators to address science content objectives at the same time. This possibility exists because content knowledge is part and parcel to effective critical thinking. The potential benefits of this concept include improved instructional approaches, improved student preparedness, and improved content expertise on the part of the students.

Implications for Educators

Teachers will always work to motivate students. How they go about this will vary from teacher to teacher, and will include extrinsic and intrinsic approaches. This research lends support to the existence of a relationship between critical thinking ability and intrinsic motivation. Findings show that with regard to some of the most unmotivated students, improved critical thinking skills reflected an improvement of intrinsic motivation to learn science content. Teachers who are often fatigued or disheartened by efforts to motivate students who are capable, but lack intrinsic motivation may find it beneficial to provide these students with explicit critical thinking skills instruction. Teachers may find that this instruction will prepare students for the complex thought that is often asked of them, yet seldom taught. The potential motivational benefits may alleviate time-consuming effort by teachers at pushing these students, as students begin to find motivation to learn from within themselves.

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APPENDIX

Appendix A. Lesson plan for second instructional day (90-minute block period).

1.) Review day one worksheet providing corrections (5-10 minutes). (App. B)

2.) Lecture with guided notes (20-30 minutes). (App. C)

3.) Group activity (20-30 minutes). (App. D and E)

4.) Group presentations (10-15 minutes).

5.) Closure (5-10 minutes).

6.) Objectives:

   a. The learner will state the definitions for arguments, issues, premise, and claim.

   b. The learner will be able to identify, and distinguish examples of issues, premises, and claims.

   c. The learner will be able to explain the relationship between premises, claims, and issues.

Appendix B. Review of material using worksheet from day one.

Day one Worksheet:

Name________________ Date____________

Please label the following as Declarative Knowledge (DK), Concepts (C), Rule (R), or Cognitive Strategy (CS).

1. There are three Major Oceans. ______
2. Explain the relationship between cold water and ocean nutrients. _____
3. Benthic zone, and Palegic zone ______
4. If the top of a wave moves faster than the bottom of the wave, then it will break____
5. Gyres in the northern hemisphere flow clockwise. _____
6. This gyre is in the northern hemisphere, so it flows clockwise. ______
7. Determine the wave speed of a wave with wavelength of 216m and a period 12secs. ______
8. Neep tide and spring tide. ____
9. When light bends it is called refraction. ____

From the paragraph below, please pick out and rewrite examples of Declarative Knowledge, Concepts, Rules, and Cognitive Strategies and label them in the space below the paragraph.

The ocean is full of living animals. There are three groups of living animals. There are plankton, nekton, and benthos. Plankton are microscopic animals that live on the surface of oceans where there is sufficient life. Nekton are ocean animals that can swim, and benthos are animals that live on the ocean floor. Knowing this, I can put a list of ocean animals into a group based on their characteristics.

Appendix C. Lecture notes for day two: Structure of Arguments.

Notes 20-30 minutes:

Argument- series of statements designed to lead to a particular conclusion.

Structure of an Argument

1. Issue- point of contention or uncertainty around which an argument is based.
    a. Examples
        i. Should we or should we not rely on nuclear power for energy.
        ii. Is there or is there not life on Mars.
        iii. Should a newly discovered species be classified as benthos or nekton.
2. Premise-proposition in an argument that a conclusion or claim is based on.
    a. Characteristics
        i. Can be singular (have only one premise)
        ii. Can have more than one (primary and secondary etc.)
    b. Indicators
        i. Since
        ii. As
        iii. Because
    c. Examples.
        i. Since the moon moves around the earth.
        ii. The earth orbits the sun.
        iii. Because the moons gravity pulls on the earth

3. Conclusion or Claim- result indicated by a proposition or propositions.
    a. Characteristics
        i. Can be singular
        ii. Can have more than one (primary and secondary)
        iii. Must be preceded by or based on at least on premise
    b. Indicators
        i. Therefore
        ii. So
        iii. As a result
        iv. Suggesting, proving, or showing that
        v. Must
    c. Examples (claims based on earlier premises examples)
        i. It must cause the tides.
        ii. Therefore, the moon must go around the sun.
        iii. It suggests that the moon causes the tidal bulge.
4. One or more premises support claims.
5. Decisions about issues are supported by one or more claims.

Appendix D. Activity for day two.

1. Materials
    a. Large bag of gumdrops
    b. 200 multiple colored pipe cleaners (one color for each group)
2. Activity
    a. Divide students into groups of 3 to four students.
    b. Have one student from each group come up and get 20 gum drops.
    c. Have a second student come up and get 20 pipe cleaners of the same color.
    d. Have one student come up and get a copy of the argument worksheet (see below).
    e. Allow students 20-30 minutes to identify all the premises and all the individual claims in the argument. They will then work to build a structural model of the internal framework for the argument using the pipe cleaners and gumdrops to make a model of the argument.
    f. Following completion of the task (teacher may have to circulate to assist students) allow 2-3 minutes for each group to present their structural model to the class. The groups must indicate what text is represented by each part of their model.
3. Finish class by reviewing material. (drawing diagrams reflecting the structure of argument if necessary).

Appendix E. Sample argument for use with gumdrop activity.

Note to teacher: Argumentative paragraph was based on issues in science but could be adapted to any relevant content. This argument was intentionally flawed to present students with a valid (structurally correct), sound (all premises and claims are true), but still leading to a wrong conclusion about the central issue.

Gumdrop Argument

You can look up into the sky and see the sun and the stars. Since the sun rises in the east and sets in the west it must be moving. It is light on the other side of the earth when it is dark here so the sun must move to that side. The stars move across the sky too so therefore they must be moving. When I stand still I do not feel like I am moving, so the earth must be still. If the earth is not moving, but the sun and the stars are moving, then it proves that they are circling around the earth. So it stands to reason that the earth is the center of the universe.