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Improved Critical Thinking Skills as a Result of Direct Instruction and Their Relationship to Academic Achievement

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IMPROVED CRITICAL THINKING SKILLS AS A RESULT OF DIRECT
INSTRUCTION AND THEIR RELATIONSHIP TO ACADEMIC ACHIEVEMENT

A Dissertation

Submitted to the Graduate Studies and Research

in Partial Fulfillment of the

Requirements for the Degree

Doctor of Education

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This experimental study examined the effect of direct instruction in critical thinking on the critical thinking ability and academic achievement of Freshman students being tutored in repeat courses at a rural southeastern Pennsylvania university. This study used the Thinker's Guides, based on Richard Paul's model of critical thinking, and the Rationale Argument Mapping Program, based on the research of Tim van Gelder. Subjects' abstract reasoning and problem solving skills were measured by the Category Test: Computer Version – Research Edition (CAT:CV). Subjects' critical thinking skills were measured pre- and post-instruction using the California Critical Thinking Skills Test – Form 2000 (CCTST – 2000). Data were analyzed to determine the ability of the CAT:CV and the CCTST – 2000 Post-test Total Ranked Score to predict subjects' improvement in critical thinking skills and academic achievement following instruction. Data were also analyzed to determine the effect of direct instruction using the Thinkers Guides or Rationale on the improvement of subjects' critical thinking skills (CCTST-2000 total and subscale scores) and final grades.

Data analysis using MANCOVA revealed no significant relationship between the intervention method and subjects' post-test critical thinking skills. However, the Thinker's Guides Group and the Control Group demonstrated improvement in academic achievement. Multiple Linear Regression revealed that the CAT:CV and the CCTST – 2000 predicted subjects' final grades, but a more significant contribution to final grades was from the CAT:CV. MANOVA results revealed no significant findings regarding the effect of intervention group on subjects' CCTST – 2000 subscale scores. Finally, data were analyzed to determine the relationship between sex and the improvement of critical thinking and academic achievement. Sex was not a significant factor for this study.

Students repeating courses demonstrated improved academic achievement based on final grade, but the effect cannot be attributed to intervention method alone. These findings suggest that further research is needed using a larger sample size to determine the extent to which direct instruction using the Thinker's Guides and the Rationale Argument Mapping Program as a supplement to tutoring can improve students' critical thinking ability and academic achievement.

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To my husband and close family members, I would like to offer my gratitude for your years of patience. I would like to thank my close friends for still being there throughout this long process. I would also like to thank my feline friends for understanding my limits on time and ability to play with them. Catnip mice and fresh tuna will be your rewards!

Finally, to my mother, I dedicate this research and acknowledge her for the patience and assistance only a mother can provide. Thanks for all of your support and understanding with my struggles during this process and your belief in my ability to achieve.

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CHAPTER ONE

THE PROBLEM

Introduction

The ability to analyze, solve problems, reason, and think critically has been the foundation for the success and progress of the human race. These abilities have helped society move into an age of technology that was a mere fantasy to their ancestors.

Societies that are technologically complex and information rich need individuals who are able to analyze the source, content, and quality of information critically and utilize that information effectively (Halpern, 1998).

Although there is ample evidence that Socrates used critical thinking as an approach to learning over 2,000 years ago, it is John Dewey, American philosopher, psychologist, and educator who is considered the *father* of the modern critical thinking tradition (Fisher, 2001). According to Dewey (1933), the central purpose of education is learning to think. In "How We Think", Dewey (1910) reports a need for 'training thought':

...it is ...the business of education...to cultivate deep-seated and effective habits of discriminating tested beliefs from mere assertions, guesses, and opinions; to develop a lively, sincere, and open-minded preference for conclusions that are properly grounded, and to ingrain into the individual's working habits methods of inquiry and reasoning appropriate to the various problems that present themselves...The formation of these habits is the Training of Mind.

Educational institutions have a major responsibility to provide the tools and learning opportunities that enable students to develop these abilities.

If Socrates and Dewey were alive to critique our educational institutions from kindergarten to post-secondary, they would probably decide that they are failing to help students develop the critical thinking skills needed to function in the 21st century where global competition and advanced technology are the norms. This conclusion would probably be supported by many educators and scholars throughout the world who recognize the deficiencies that many students exhibit in critical thinking.

The United States Department of Education and other governmental agencies recognize American students' deficiencies in critical thinking and the need to educate students to develop these skills. Critical thinking and abstract reasoning skills have been the target of research by the United States Department of Education. The focus of that research prompted the sponsoring of a report in 1988 conducted by the Educational Testing Service on reading and critical thinking skills of public and private school students at the K-12 and post-secondary levels. The results of this study revealed that students do not learn to analyze what they read nor do they communicate their ideas effectively (Piro and Iorio 1990).

Statement of the Problem

Students continue to enter post-secondary institutions directly after their completion of high school, but only 23% of students perform at the highest level in critical thinking exercises (Piro & Iorio, 1990). Post-secondary institutions are

not performing much better. Halpern (1998), reports that post-secondary education's effect on the critical thinking skills of its graduates is limited.

In 1992, the United States Department of Education sponsored national research on the critical thinking skills of adults. The purpose of this research was to send a clear message to higher education that greater accountability regarding teaching and student learning is expected. This research also sends a message to students early in their post-secondary endeavors that there are greater expectations for them to improve their thinking ability (Greenwood, 1992).

Facione, Sanchez, and Facione (1993) report a broad consensus among theorists of critical thinking who suggest that education's goal is to prepare individuals, particularly those at the post-secondary level, who willingly and skillfully engage in critical thinking.

A baccalaureate education should produce graduates who are willing and able to use their cognitive powers of analysis, interpretation, inference, evaluation, explanation, and self-monitoring meta-cognition to make purposeful judgments about what to do or not to do (Paul, 1984; Ennis, 1985; Kuhn & Dean, 2004; APA, 1990; Carter-Wells, 1992).

Although there is a general expectation that post-secondary students are equipped with critical thinking skills and know how to use them, many scholars report that most college students display inadequate levels of critical thinking (Tsui, 1999). According to Facione (1993), educators and scholars recommend that students in K-12 and college receive critical thinking instruction as a matter of practice throughout their curriculum in order to develop and use critical

thinking skills. Providing critical thinking as a proactive measure at the early stages of intellectual development may in fact reduce the need for reactive measures for students in higher education.

Purpose of this Study

The purpose of this study was to research the effect of direct instruction in critical thinking skills on undergraduate student levels of critical thinking and academic achievement of Freshman students. All students were tutored in courses they were repeating. This study expanded on prior research conducted by Facione (2002), Halpern (1994, 1995, 1998, 1999, 2001), Halpern & Hakel (2003), Giancarlo & Facione (2001), Paul & Nosich (1992), Paul, R. (1993), Paul & Elder (1996, 1997), Ewell (2002), Gazella & Ginther (1996), and van Gelder (2001- 2005) to assess the critical thinking skills of undergraduate students and to determine if direct instruction in these skills positively impacted their critical thinking and academic achievement to a greater extent than tutoring. Tutoring has been shown to be a useful tool to assist students at the post-secondary level. Two critical thinking skills' interventions, the Thinker's Guides and Rationale Argument Mapping Program, were used as well as two assessment measures, the Category Test Computer Version – Research Edition (CAT:CV) and the California Critical Thinking Test - Form 2000.

This study had several secondary purposes. This study investigated the relationship between students' error scores on the CAT:CV and the pre-test and post-test scores of the California Critical Thinking Skills Test – Form 2000 (CCTST-2000). The relationship between the CAT:CV and students' final grades

was also investigated. The relationship between the CAT:CV and the subscales of the CCTST-2000 was investigated to determine if there were any areas of improvement in the cognitive skills identified by the CCTST-2000. Finally, the relationship between sex and students' critical thinking skills and final grades was also assessed. According to Facione (1990), male students outperformed female students following critical thinking instruction.

If students are able to develop and improve their critical thinking skills through instruction that is not course-specific, this may result in several positive changes for students and universities. Improving critical thinking skills could potentially decrease the number of courses students repeat; reduce the likelihood of being dropped from courses and possibly from departments and/or forced to change majors; increase the likelihood of timely graduation; decrease the likelihood of financial loss due to the cost of re-taking courses; improve academic achievement; facilitate the acquisition of a greater repertoire of skills employers desire; maximize the tutoring experience; improve research abilities, particularly those developed using the internet; help students recognize that developing critical thinking is an expectation of their post-secondary education; and lend to the realization that students are ultimately responsible for their academic achievement and play an integral role in their own success.

Universities would undoubtedly benefit from students who improve their critical thinking skills. Students with excellent critical thinking skills, hold the promise to universities of 1) increased retention of all students, 2) increased persistence and graduation rates, 3) students who are able to think critically in

preparation for the workforce, 4) increased assurance for the public who expect greater accountability regarding student progress, and 5) greater community confidence in their ability to produce students who are able to become productive members of the society.

Research Questions

1. Does direct instruction in critical thinking skills using the Thinker's Guides or Rationale, as a supplement to content course tutoring, improve the critical thinking skills and academic achievement of Freshmen who are repeating a course, as measured by the California Critical Thinking Skills Test-2000 Post- test Total Score and final course grades, to a greater extent than content course tutoring alone?
2. Do abstract reasoning and critical thinking skills, as measured by the Category Test: Computer Version – Research Edition and the California Critical Thinking Skills Test-2000 predict final grade outcomes in repeated courses for Freshman students who are repeating courses?
3. Are there significant differences between Experimental Group 1, Experimental Group 2 or the Control Group on the California Critical Thinking Skills Test – 2000 Post-test Analysis, Evaluation, Inference, Deductive Reasoning, and Inductive Reasoning Subscales?
4. Is there a significant difference in the critical thinking skills and academic achievement of males vs. females following direct instruction in critical thinking skills using the Thinker's Guides or Rationale as measured

by the California Critical Thinking Skills Test-2000 Post-test Total Ranked Score, CCTST-2000 Post-test Subscale Scores, and final grades?

Hypotheses

The following are the hypotheses for this study:

1. Hypothesis H₁: - Group 3 (Control Group) will demonstrate significantly lower critical thinking and academic achievement than Groups 1 (Thinker's Guides) or 2 (Rationale). Ho:₁ - There is no significant difference between the critical thinking skills and the academic achievement of the Control Group and Groups 1 or 2.
2. Hypothesis H₂: - There will be a significant relationship between the CAT:CV error score and students' final grades and between the CCTST -2000 Post-test Total Ranked Score and students' final grades in repeat courses. Ho:₂ - There is no significant relationship between students' CAT:CV Error Score or the CCTST- 2000 Post-test Total Ranked Scores and their final grades in repeat courses.
3. Hypothesis H₃: - Experimental Group 1 will demonstrate significantly higher scores than Experimental Group 2 and the Control Group 3 on the CCTST-2000 subscales. Ho:₃ - There is no significant difference between the CCTST – 2000 post-test Analysis, Evaluation, Inference, Deductive Reasoning, and Inductive Reasoning Subscales of Groups 1, 2, and 3.
4. Hypothesis H₄: - Males will demonstrate significantly higher scores on the CCTST 2000 Post-test Total Ranked Score, CCTST-2000 Post-test Subscale Scores, and final grades than females. Ho:₄ - There are no differences

between males and females on the CCTST – 2000 Post-Test Total Ranked Scores, CCTST-2000 Post-test Subscale Scores and final grades.

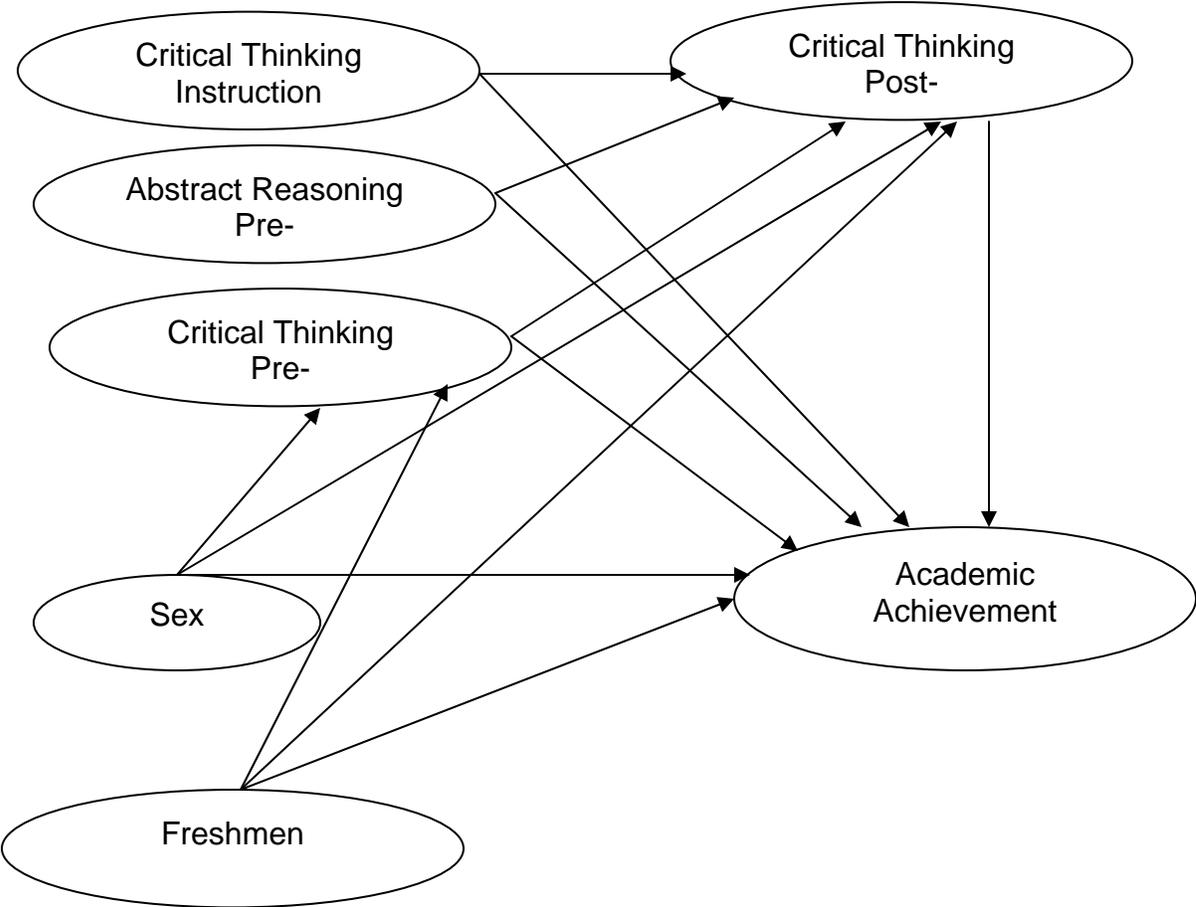


Figure 1. Research diagram on the possible effects of sex and direct instruction in critical thinking on subjects' critical thinking skills and academic achievement.

Significance of the Problem

A fundamental goal in higher education continues to be the development of critical thinking skills in college students (Clifford, Boufal, & Kurtz, 2004). Although many national and international post-secondary institutions have a required course in critical thinking that all students take as a part of their general education requirements (Halpern, 1998), there appears to be a low priority to equip all students with these skills. Presidents George H. Bush and Bill Clinton supported a goal to enhance critical thinking skills in college students by declaring it a national priority, but this priority was never funded (National Education Goals Panel, 1991). A survey was conducted by the Chronicle of Higher Education (2000) about what most Americans want from a college education in preparation for employment. Results reveal that general skills learned in critical thinking were more important than computer or other job specific skills. The survey also cited that 81% of respondents ranked critical thinking as “very important for doing their job.”

Workforces in America have changed and many college graduates are not prepared to compete in a global economy that expects individuals to be skilled in problem solving and critical thinking (Vance, 2007). While many students leave college technically savvy and prepared in specific skill areas, many of these same students are not ready for the demands of the workforce (Levine, 2005). Due to changing economies, rising populations, and global competition, employers demand employees who can function effectively and independently.

Employers often complain that their entry-level employees lack essential critical thinking skills necessary to process and refine information (Hirose, 1992).

The inability to realize one's educational and career goals are additional negative consequences of poor critical thinking. At post-secondary institutions, students with limitations in critical thinking risk delays in graduation due to poor academic performance, repetition of classes, changes in major, and loss of financial aid due to stipulations that students complete a specified number of new credits each year. In some cases, students fail to graduate. For those who do graduate with limited critical thinking skills, the workforce awaiting them poses additional difficulties.

Forty years ago, students graduating from high school could choose factory work as an alternative to college. Many planned to work in the same job until retirement. However, there has been a rude awakening for those who planned to do so. Many companies that sustained the blue collar workforce through factory work have begun to outsource their work to foreign companies where labor, manufacturing, and healthcare costs are less expensive. It is crucial now more than ever that all students have the opportunity to develop critical thinking skills that will enable them to have greater options upon graduation.

A group of experts in the instruction and assessment of critical thinking utilized the Delphi Method to form an interactive panel to discuss the cognitive skills and affective dispositions related to critical thinking. The Delphi Project of 1990 was the result of almost two years of research on critical thinking conducted

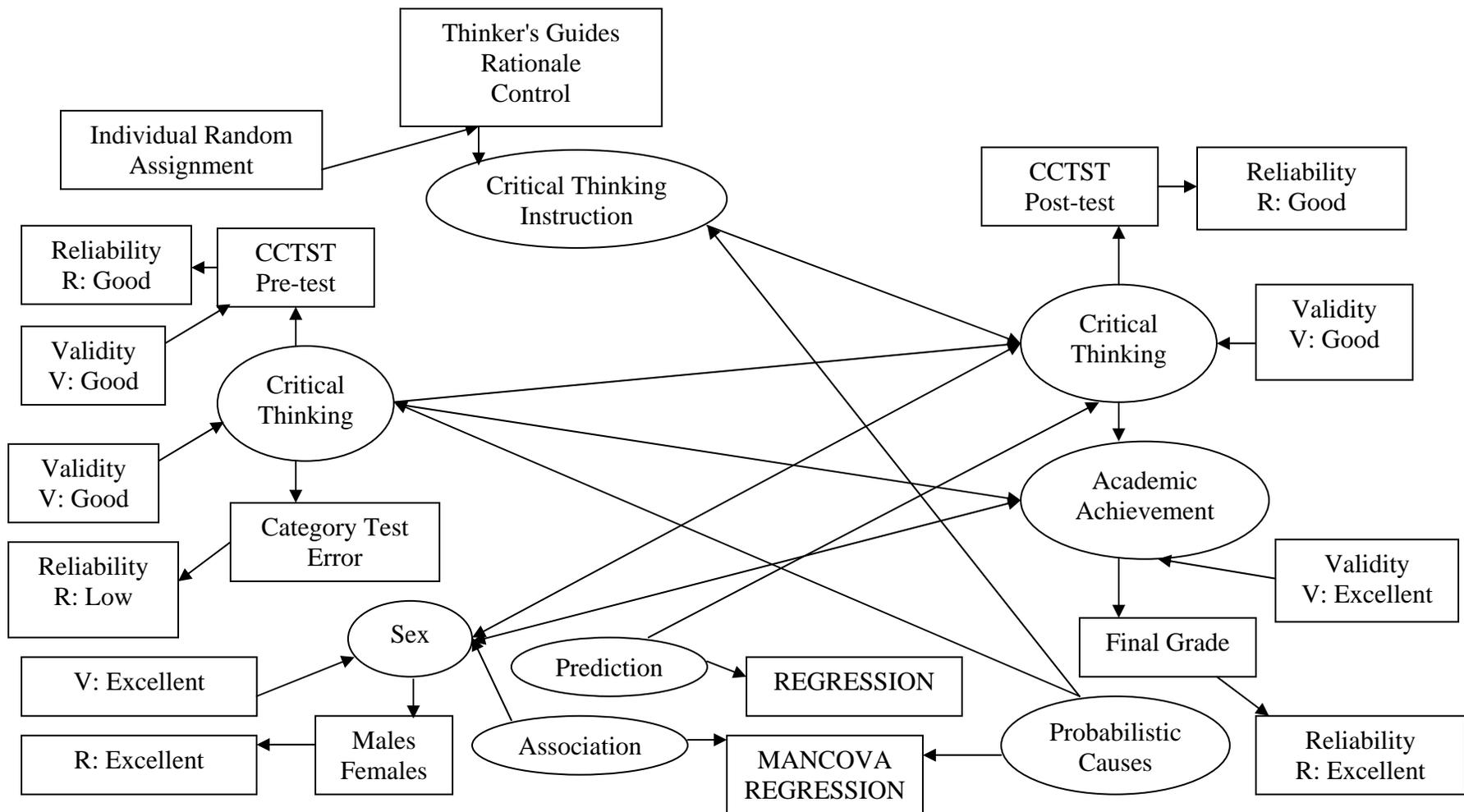


Figure 2. Research path diagram on the possible effects of sex and direct instruction on critical thinking skills and academic achievement.

by this panel. The panel initiated their analysis of critical thinking by identifying the core cognitive elements of critical thinking expected of both freshman and sophomore post-secondary students as: (1) interpretation, (2) analysis, (3) evaluation, (4) inference, (5) explanation, and (6) self-regulation, (Facione,1990).

Richard Paul (1993), a leading authority on critical thinking, expanded the elements of critical thinking identified by the Delphi Report to include: question, purpose, information, assumptions, concepts, point of view, and implications. Linda Elder, a leading researcher in critical thinking, has also contributed factors related to the improvement of these skills for students at the college level.

Critical Thinking Measures

Paul and Elder have taken the cognitive elements of critical thinking and the characteristics of good critical thinkers from prior research projects, including the Delphi Report, and expanded on them to address the current critical thinking needs of students at all levels. They developed a series of tools entitled “The Thinkers Guides” to teach critical thinking skills at the post-secondary level.

Researcher Tim van Gelder (2005) reports that students must engage in critical thinking rather than just learning about it, because just learning about it does not increase these skills. van Gelder (2005) feels that active deliberate engagement in critical thinking exercises using argument mapping gives students the opportunity to become better critical thinkers. Mapping out reasoning through the use of argument maps allows students to monitor their reasoning, identify important issues and assumptions and more easily clarify their insights (van Gelder, 2005).

Rationale claims to achieve significant gains in critical thinking skills among undergraduate students. Rationale uses argument maps that are computer-generated allowing for an interactive approach that builds and evaluates students' arguments. The program provides guidance in developing arguments, scaffolding, feedback, and motivation to transfer and use critical thinking skills (van Gelder, 2001).

Rationale has been used for undergraduate students who were pre-tested and post- tested using the California Critical Thinking Skills Test. Test results revealed that students showed improvement in critical thinking skills by approximately one standard deviation when compared to other direct methods of teaching critical thinking skills (van Gelder, 2001).

Impact of Poor Critical Thinking

Life presents a host of challenges for most people. The decisions one makes about education, career, family, short and long term goals are all impacted by the critical thinking skills available to make those decisions. The ability to function in a community, society, and as a citizen is also impacted by critical thinking skills. Inadequate or faulty critical thinking may result in unexpected challenges in life.

Research reveals that post-secondary institutions are failing in their efforts to equip students with the necessary critical thinking skills. Therefore, it is no surprise that the retention of students at the post-secondary level is an ongoing challenge. Universities nationwide, including the Pennsylvania State System of

Higher Education (PASSHE), have large numbers of students each year who repeat courses multiple times, despite content course tutoring.

Students often fail to meet departmental requirements for majors. Many students are forced to change majors, delay graduation, or fail to graduate due to poor academic performance that may be partly based on deficient critical thinking skills. Content-course tutoring alone does not appear to decrease the number of repeat courses per semester. Freshman students may be particularly at risk if they are entering colleges with poor critical thinking skills.

At Millersville University of Pennsylvania, approximately 900 students repeat courses each semester. It is not uncommon for these students to repeat the same courses two or more times. In the PASSHE, the exact number of repeat courses has not been documented in available form except those compiled for Millersville University of Pennsylvania.

Schools within the PASSHE have varying repeat course standards, but Millersville University is the only university in the system that systematically enforces its repeat-course policy. The policy dictates that students who repeat the same course three or more times can be dropped from the course. Students who are dropped from the course they are repeating may fail to meet departmental requirements and may ultimately be dropped from their respective departments. The repeat course policy serves as a catalyst to encourage students to take appropriate measures to improve their academic performance and seek services to assist them. Failure to meet educational goals significantly impacts retention, which may be attributed to deficiencies in critical thinking skills.

Definitions

The following definitions of terms were used in this study:

Abstract Reasoning - The ability to analyze information and solve problems on a complex, thought-based level by using tasks that involve skills such as: forming theories about the nature of objects, ideas, processes, and problem solving; understanding subjects on a complex level through complex analysis and evaluation; and the ability to apply knowledge in problem-solving using theory, metaphor, or complex analogy.

Argument –The ability to distinguish a communication that presents a claim with one or more supporting reasons from a communication that simply describes or explains (Jones & Ratcliffe, 1993).

Argument Map – A graphic method to illustrate the structure of reasoning and argumentation (Austhink, www.austhink.com).

Assumption –Something we take for granted or presuppose usually related to something we know and do not question (Elder and Paul, 2002).

Critical Thinking – The definition of critical thinking developed by the Delphi Panel, consisting of 46 experts from various disciplines, in the research project entitled Critical thinking: A statement of expert consensus for purposes of educational assessment and instruction: research findings and recommendations (Facione, 1990), which resulted in the Delphi Report, were used for this study.

The consensus is that critical thinking is purposeful, self-regulatory judgment that results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological,

criteriological, or contextual considerations upon which that judgment is based. Critical thinking is essential as a tool of inquiry. As such, critical thinking is a liberating force in education and a powerful resource in one's personal and civic life...While not synonymous with good thinking; critical thinking is a pervasive and self-rectifying human phenomenon (APA, 1990).

Deductive Reasoning – A conclusion that is true based on fact. Reasoning occurs when a general fact progresses to a specific conclusion. A conclusion is reached when something is logically sound and the conclusions are sound because they are based on fact.

Inductive Reasoning – Observations that are used to support or suggest a conclusion even though the conclusion can never be proven (Halpern, 2003).

Reasoning - The systematic inferring of information according to rules of logic to demonstrate or ascertain the validity of a claim or an assertion (Jones & Ratcliffe, 1993).

Inference – A step of the mind, an intellectual act, by which one concludes that something is true in light of something else being true, or something to be true. Inferences may be accurate or inaccurate (Elder & Paul 2002).

Assumptions

There are many variables associated with critical thinking and academic achievement that may impact student performance. The extent of the relationship between variables provides insight into overall student performance. Prior exposure to critical thinking instruction, repeat tutoring, length of intervention,

treatment interventions, age, race, gender, and year in college may be some of these variables.

Based on research, it is assumed that students in this study possess under-developed critical thinking skills as first-time Freshmen. It is assumed that students have not had previous exposure to the Category Test: Computer Version or the California Critical Thinking Skills Test – Form 2000 because both are generally used at the post-secondary level.

Delimitations

There are several factors that affect the generalizability of the results of this study to other student populations. Many of the students who volunteered for this study share similar characteristics with those accepted at Millersville University such as the number of courses they repeated and low average abstract reasoning and problem solving skills determined by the CAT:CV. Students came from only one institution. Students at the institution have similar characteristics that may only be generalizable when compared to institutions of similar size with students who share similar characteristics.

There are also threats to the external validity of this study that may affect the generalizability of results to other student populations. Interventions were limited to students who repeated courses one or more times. Interventions were provided in small groups that mimicked their tutoring situations. Even though all interventions were implemented equally, there can be no guarantee about the integrity in which interventions were provided.

Finally, novelty affects performance. It is not unusual for students to improve just because an intervention is different from their current style of learning. Interventions break up the boredom and allow students to re-focus their attention during novel situations to make them more available for learning. Unfortunately, there is no guarantee that the effects of interventions are substantial enough to minimize recurring boredom that may jeopardize continued interventions. Students may again get bored with the length of treatment and decide to put their attention elsewhere.

Pre-tests and post- tests are also threats because of their effect on statistical regression that can result in extreme scores that improve or move closer to the mean. Both pre-tests and post- tests were the same form (2000) of the California Critical Thinking Skills Test. Although Insight Assessment identifies Form 2000 as a test that can be used for both pre-tests and post- tests, it is possible that learning from the pre- test affected post- test performance.

Limitations

There are obvious limitations to this study. First and foremost was the limited experimental period of thirteen weeks for the study. Some research suggests that successful interventions should span the period of one college semester, which can last fifteen to sixteen weeks, or an entire academic year to determine increases in critical thinking. Other research suggests providing interventions that span the entire K-12 and post-secondary education of students. However, during the thirteen-week intervention, students became more aware of their strengths and weaknesses in critical thinking and also had

opportunities to apply skills across their courses, rather than more traditional methods of critical thinking that are course specific.

There were undoubtedly additional threats to internal validity for this study. It is possible that intervention results showed students who made great gains in critical thinking skills, when in fact they already possessed adequate skills but did not use them. Other students who were receiving ongoing content course tutoring at the same time they engaged in critical thinking training may have received similar intervention techniques from their tutors.

Students often get bored with research studies that may decrease their commitment and lead to discontinuing participation. Pre-testing and post-testing could be problematic for savvy students who were alerted to presumed expectations for their performance. There are no guarantees about the level of incidental skills acquired by student participants that could have made a difference in student performance in post-testing.

Summary

Post-secondary institutions expect students to enter college with well developed critical thinking; however, the reality is that they do not. The need to improve the critical thinking skills of post-secondary students is based on the numerous research studies suggesting that students lack adequate critical thinking skills. Research suggests that it is imperative for educational institutions to improve the reasoning and critical thinking skills of America's students. Traditional instruction may be failing a large majority of students who graduate without the skills necessary to succeed.

Research suggests that America's post-secondary students must be prepared for the ever-changing workforce; one that relies heavily upon workers with job specific and well-developed critical thinking skills. Workers are also expected to possess these skills to be able to keep up with the demands of technology. Research suggests that the critical thinking skills of America's youth must be improved in order to do so. Even though research substantiates this crucial need, little has been done to intervene because of the lack of agreement on how best to teach critical thinking skills.

For years, post-secondary institutions attempted to improve students' critical thinking skills by supplementing instruction with content course tutoring and by teaching these skills outside the general course curriculum. The results are not always positive. Based on research studies, these efforts are falling short in providing students with the tools to think and analyze information critically. Students repeat courses despite content course tutoring and the repetition of courses negatively impacts their ability to graduate in their intended major or results in a failure to graduate.

America's youth cannot wait for the results of ongoing debate about an issue that suggests students are not prepared for careers requiring well developed critical thinking. This issue must be addressed now to avoid another group of graduating students who cannot meet the demands of the workforce.

CHAPTER TWO

REVIEW OF LITERATURE

This chapter is a review of the relevant literature regarding the concept of critical thinking and the role of critical thinking for students at the post-secondary level. This chapter is divided into the following sections: (1) history of critical thinking; (2) definitions of critical thinking; (3) factors impacting student retention at the post-secondary level; (4) educational institutions' accountability; (5) the importance of teaching students to think critically; (6) the debate over how to teach students to think critically (7) cognitive skills associated with critical thinking (8) assessment of critical thinking; (9) methods to improve the critical thinking skills of college students; and (10) a summary of the critical thinking literature used in this study. Finally, the results of this literature review provided the foundation for the experimental design used in Chapter Three to determine if direct instruction and practice in critical thinking skills can improve the critical thinking skills and academic achievement of post-secondary students who have a history of failing and repeating courses despite receiving tutoring in those courses. (See Figure 2)

History of Critical Thinking

Over 2,500 years ago, Socrates came to the realization that when challenged, most people can not justify their knowledge through reasoning or evidence. He found that many people in positions of authority are rarely dependable regarding sound knowledge and insight; rather, they often display confusion and irrational thought when attempting to justify their knowledge (Paul,

Elder, & Bartell, 1997). Socrates uncovered this through probing questions that challenged the veracity of claims made by those seen as the authority figures of his day. Unfortunately, when challenged, Socrates found that information presented as expert knowledge could not withstand questioning and deliberate scrutiny for verifiable evidence, clarity, and logical consistency (Paul, Elder, & Bartell, 1997).

Socrates' style of probing questioning that demanded evidence and logic while analyzing reasons, assumptions and the implications of what is said and done in this process is the foundation for the Socratic method of questioning (Paul, Elder, & Bartell, 1997). The Socratic Method asks thinkers to reach beyond common beliefs and explanations by challenging them to use logic and reason to support their conclusions. The Socratic Method is one of the most well-known strategies to teach critical thinking (Paul, Elder, & Bartell, 1997).

Plato followed the work of Socrates and recorded much of Socrates' work. According to Carroll (2004), Plato held great admiration for Socrates as he defended himself against the government of Greece for encouraging independent thought among its youth. In Plato's work, *The Apology*, which highlights Socrates' defense, he reports that

the death sentence handed down to him would guarantee that he would be known to history as a heroic figure, one who died for the "crime" of thinking for himself and for encouraging others to do likewise (Carroll, 2004).

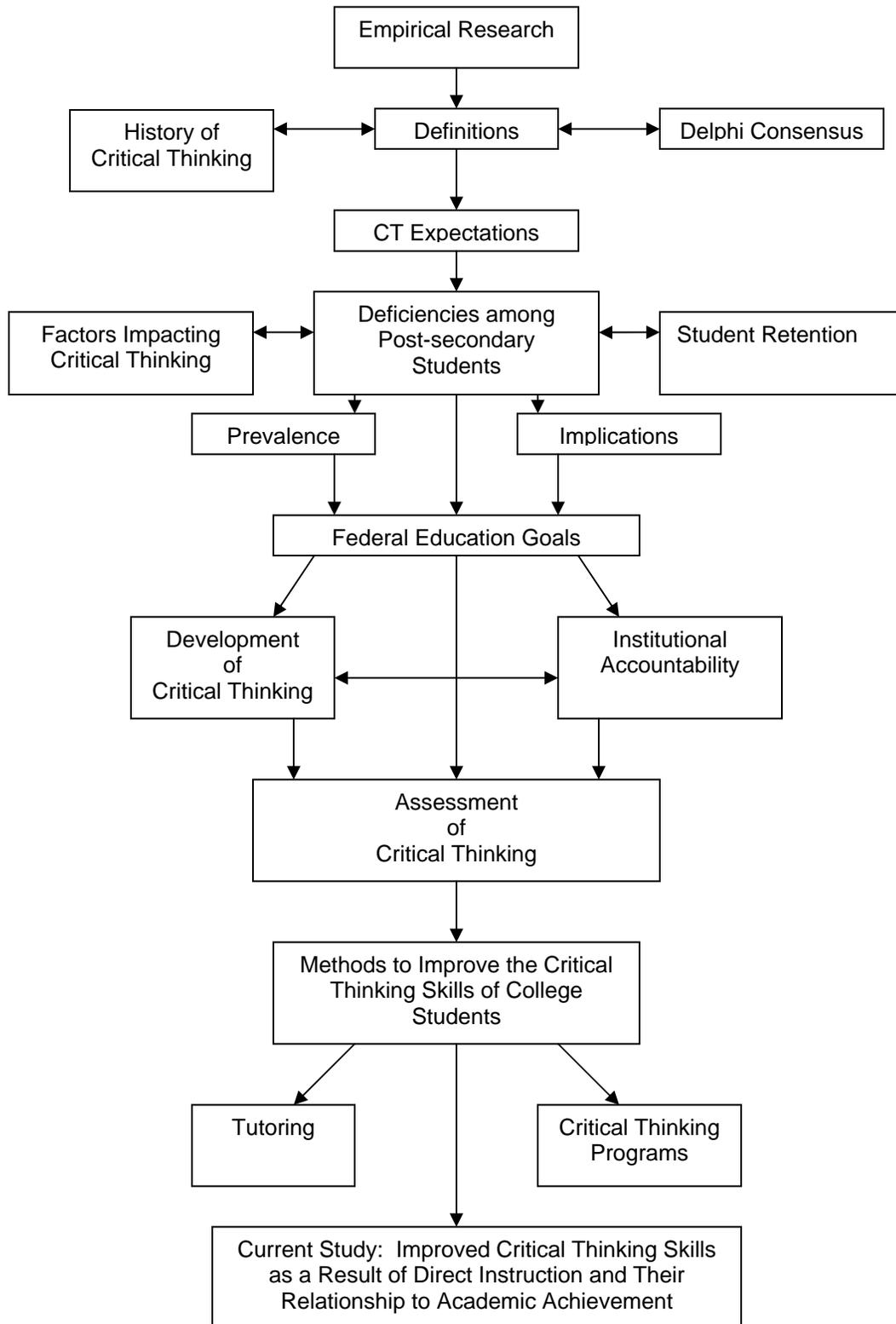


Figure 3. Literature Review Research Diagram.

Thomas Aquinas was well-known in the middle ages for his systematic approach to critical thinking. Aquinas tested his thinking to ensure it was indeed critical thinking by stating, considering and answering all criticisms of his thinking process that he found crucial to its development (Carroll, 2004).

By the Renaissance, scholars of critical thinking were numerous, particularly in Europe. Many disciplines such as art, law, religion, etc. were associated with everyday life and found prime for analysis using critical thinking (Paul, Elder, & Bartell, 1997).

In the late 16th century, Francis Bacon in his writings declared that the nature and tendency of man was to come to conclusions that were not always based on fact. In his text, *The Advancement of Learning*, Bacon claimed that information must be processed and gathered in an empirical fashion (Paul, Elder, & Bartell, 1997). Bacon is known in philosophy for his application of inductive reasoning, a process in which information is gathered from actual observations and experiences that can stand up to rigorous testing that leads to a theory.

In the early 17th century, French philosopher Rene Descartes made a name for himself as the founder of the *principle of systematic doubt*. Descartes was a skilled mathematician who invented analytic geometry. He believed there is a systematic approach to determining the validity of information. Descartes authored the book, *Rules for the Direction of the Mind*, which argues the need for a special “disciplining of the mind” to guide the thinking process (Paul, Elder, & Bartell, 1997). Descartes is considered the “father of modern philosophy” and the “father of modern mathematics” (Burnham & Fieser, 2005). He is most well-

known for the phrase “I think, therefore I am.” Descartes’ writings continue to be studied in the 21st century.

During the Italian Renaissance, Niccolo Machiavelli came to the forefront with his work entitled “The Prince” in which he critically assessed the political environment of his era. He was able to awaken the general public about the necessity to recognize the real agendas of the rulers as well as the contradictions and inconsistencies of politics in general (Paul, Elder, & Bartell, 1997). In his book, *The Discourse*, Machiavelli writes about the development, structure, and a series of checks and balances in government that may be the foundation of today’s democratic societies (Wikipedia).

According to Paul, Elder, & Bartell (1997), Thomas Hobbes and John Locke (16th and 17th century) displayed confidence in critical thinking as well. Hobbes held a naturalistic view claiming that reasoning and evidence could explain everything in the world. Locke, on the other hand, felt that common sense should be the driving force in the analysis of life and thought. Although Hobbes and Locke differed in their approaches to critical thinking, they both viewed it as an opportunity to open one up to new avenues for learning. The works of Robert Boyle are also notable in the 17th century. Boyle is best known through his work *Sceptical Chymist*, in which he criticized chemical theory (Paul, Elder, & Bartell, 1997).

Sir Isaac Newton was a scholar from the 18th century whose works greatly influenced scientific thinking. Newton invented a scientific method as a set of four

rules for scientific reasoning. These rules were stated in the *Principia* and proposed that:

(1) we are to admit no more causes of natural things such as are both true and sufficient to explain their appearances, (2) the same natural effects must be assigned to the same causes, (3) qualities of bodies are to be esteemed as universal, and (4) propositions deduced from observation of phenomena should be viewed as accurate until other phenomena contradict them.

Soren Kirkegaard and Friedrich Nietzsche were two notable scholars from the 18th century. Both critics of rationality, idealism, and builders of philosophical systems, they also espoused the importance of the position of the individual, personality, and subjectivity (Brobjer, 2003). Kirkegaard's and Nietzsche's works are used to develop critical thinking skills in students enrolled in 21st century philosophy courses.

Definitions of Critical Thinking

The concept of critical thinking has undergone centuries of development from Socrates to modern-day theorists. Therefore, there are numerous definitions of critical thinking. However, it was John Dewey who defined critical thinking as "reflective thinking" that is:

active, persistent, and careful consideration of a belief or supposed form of knowledge in light of the grounds which support it and the further conclusions to which it tends (Dewey, 1933).

Dewey outlined the necessity for individuals to actively and persistently participate in their own thinking process. By definition, “reflective thinking” encourages individuals to carefully consider their thought process so that premature conclusions are not reached in haste.

Fisher (2001) further delineated Dewey’s definition of critical thinking to describe it as an active process whereby one thinks independently, raising questions, while persisting in the use of relevant information to skillfully reason logical conclusions. Fisher (2001) points out that reasoning and the implications of reasoning are crucial to the process of critical thinking because of their role in shaping one’s beliefs.

Edward Glaser expanded on Dewey’s definition of critical thinking by defining it as:

1) an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one’s experience; 2) knowledge of the methods of logical enquiry and reasoning; and 3) some skill in applying those methods. Critical thinking calls for a persistent effort to examine any belief or supposed form of knowledge in the light of evidence that supports it and the further conclusions to which it tends (Glaser, 1941).

Although Glaser’s definition of critical thinking is very similar to Dewey’s, he identifies the need for evidence to support one’s conclusions. Glaser also recognizes the necessity of the disposition to use critical thinking skills, which he finds equally important to having them (Fisher, 2001). Glaser developed the

Watson-Glaser Critical Thinking Appraisal, which is widely used today as an assessment tool of critical thinking.

Glaser also recognized essential abilities required for the process of critical thinking. The process of critical thinking requires one to do the following:

- 1) To recognize problems, 2) to find workable means for meeting those problems, 3) to gather and marshal pertinent information, 4) to recognize unstated assumptions and values, 5) to comprehend and use language with accuracy, clarity, and discrimination, 6) to interpret evidence, 7) to appraise evidence and evaluate statements, 8) to recognize the existence of logical relationships between prepositions, 9) to draw warranted conclusions and generalizations, 10) to put to the test the generalizations and conclusions at which one arrives, 11) to reconstruct one's patterns of beliefs on the basis of wider experience, and 12) to render accurate judgments about specific things and qualities in everyday life (Glaser, 1941).

Robert Ennis (1993) carried Dewey's definition of critical thinking to a level that considered one's decisions and actions as integral components of critical thinking.

Critical thinking (CT) is reasonable, reflective thinking that is focused on deciding or believing what to do (Norris et al, 1989).

Richard Paul took critical thinking to the next level by considering meta-cognition as a crucial component of critical thinking. Paul's consideration of meta-

cognition is in agreement with teachers and researchers of critical thinking who feel that individuals must remain cognizant of their own thinking process (Fisher, 2001). Paul's definition of critical thinking is:

Critical thinking is disciplined, self-directed thinking which exemplifies the perfection of thinking appropriate to a particular mode or domain of thinking – about any subject, content or problem in which the thinker improves the quality of his or her thinking by skillfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them (Paul, Fisher, & Nosich, 1993).

Richard Paul elaborates further on the concept of critical thinking by proposing that central to critical thinking are two components, a question or problem and its associated reasoning. Paul and Nosich (1991) assert that good reasoning has integral components that are described as cognitive elements of thought identified as:

1. Purpose, goal: Reasoning is goal directed in order to achieve an objective.
2. Question, issue or problem: Reasoning to answer or solve at least one question, issue or problem
3. Point of reference or view: Reasoning must occur within some point of reference or view.
4. Empirical dimension of reasoning: Reasoning must include information such as data or evidence to scrutinize.
5. Conceptual dimension of reasoning: All reasoning uses concepts, theories, and principles that may show weaknesses when evaluated.

6. Assumptions: All reasoning includes presuppositions and taking things for granted.
7. Implication and consequences: All reasoning will undoubtedly show strengths and weaknesses as it develops.

McPeck defines critical thinking as the skill and propensity to engage in an activity with reflective skepticism that includes both actions and beliefs in the scope of critical thinking (Jones & Ratcliff, 1993).

Michael Scriven's definition of critical thinking is also noteworthy because he sees critical thinking as essential as reading and writing. His definition of critical thinking suggests that as an academic skill:

Critical thinking is skilled and active interpretation and evaluation of observations and communications, information and argumentation (Fisher & Scriven, 1997).

Diane Halpern (1996) defines critical thinking as the following:

Critical thinking is the use of those cognitive skills or strategies that increases the probability of a desirable outcome. It is used to describe thinking that is purposeful, reasoned and goal directed – the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions when the thinker is using skills that are thoughtful and effective for the particular context and type of thinking task. Critical thinking also involves evaluating the thinking process – the reasoning that went into the conclusion we've arrived at and the kinds of factors considered

in making a decision. Critical thinking is sometimes called directed thinking because it focuses on a desired outcome.

Finally, the definition that resulted from the input of 46 experts on the Delphi Panel cited in Peter Facione's Delphi Report defines critical thinking as: purposeful, self-regulatory judgment, which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteria logical, or contextual considerations upon which that judgment is based.

Facione (1990) also reported that the cognitive skills one draws upon to skillfully engage in critical thinking may not be sufficient without the affective dispositions to use those skills. Facione (1990) asserts that individuals may possess the cognitive skills necessary for skilled reasoning, but getting them to use these skills may present another hurdle. Finally, there is consensus among some of the leaders in critical thinking research that critical thinking should include meta-cognition as an integral component to help one be aware and monitor his or her thinking (Halpern, 1992; Facione, 1990, Marzano, 1998; and Paul & Nosich, 1991).

The consensus of the Delphi Panel regarding the definition of critical thinking was the definition accepted for this study. The Delphi Panel was composed of psychologists, philosophers, social sciences, etc., all of whom provided input that considered the aspects of critical thinking that reach across disciplines.

Factors Impacting Student Retention at the Post-secondary Level

Retention

Retention of students is a topic of ongoing concern at most colleges and universities. States collect data to determine the yearly retention rates of their students. According to the National Information Center for State Higher Education Policy and Analysis' 2002 report, Pennsylvania is among the few states with a retention rate of over 82% for returning freshman. This freshman retention rate is surpassed by only five other states: Delaware, Maryland, Massachusetts California, and Connecticut. Universities look at returning students as well as graduation rates. Universities also look at the number of students returning each year at each level because graduation rates may not tell the whole story about student retention.

Pre-college Preparation

Government agencies agree that it is the responsibility of educational institutions to promote and create learning environments that develop higher-order thinking skills such as critical thinking. However, in their research on the preparedness of students for post-secondary education, the United States Department of Education found that most students are under-prepared in basic science, math, writing, and reading (Education Commission of the States, 2002). Research also indicates that mainstream students are not faring much better in college preparation. The U.S. Department of Education reported that students should acquire basic reading and literacy skills by the end of third grade, basic understanding of algebra and geometry by eighth grade and should have

experienced advanced science by twelfth grade. Unfortunately, this same report revealed that a significant portion of eighth graders in the U.S. are not prepared for college preparatory programs; 68% scored below proficiency in reading, 71% scored below proficiency in math, and 70% scored below proficiency in science and writing (ECS, 2002).

Regardless of their pre-college preparation, there is a general expectation in higher education that post-secondary students should enter colleges and universities equipped with critical thinking skills. However, because of the lack of preparedness in the basics, schools have become so focused on general academics that efforts to enhance the development of critical thinking skills in their students are minimal. The emphasis on the basics is facilitated by academic deficiencies and the federal demands for schools to improve academic achievement through *No Child Left Behind*. Ironically, it may be the development of critical thinking skills that is missing in the drive to improve students' academic performance. As a result, students continue to enter colleges and universities with deficiencies in reading, mathematics, writing, and critical thinking skills, the very tools necessary to achieve at the post-secondary level and beyond (Ewell, 2002). Freshman students are particularly at-risk during their first year of post-secondary study due to deficiencies in these skills (Chaplin, 2007).

Socio-economic Status

Research indicates that there is a relationship between academic performance and socio-economic background. Students from higher socio-economic backgrounds are more likely to successfully complete college because

of their excellence in critical thinking skills (Cheung, Rudowicz, & Lang, 2001). Many of these students have parents with advanced education, school districts with greater resources, and access to advanced technology.

Conversely, it is expected that students from low socio-economic backgrounds may be less academically skilled, have poorer critical thinking skills, and less resources from which to draw than students from higher socio-economic levels. Early intervention for these students is crucial and should be a priority (Cheung, Rudowicz, & Lang, 2001).

According to the Chronicle of Higher Education (April 2004), there continues to be a large gap between the number of students entering institutions of higher education and the number of students obtaining degrees. Finances account for part of this gap; 20% of poor students obtain degrees while their affluent counterparts obtain degrees at a rate of 70%. Poor students are often viewed as at-risk students because the research suggests they are generally unprepared for college. They may typically be identified as students of color, particularly African-American and Hispanic, non-traditional students, and even older individuals or those seeking advanced education for a new career (Horn, & Chen, 1998).

The Institute for Higher Education Policy (2005) pursued further research into the issue of finances. Their data indicate that students from low income families are more often enrolled in non-college preparation tracks in high school and are unprepared for college entrance exams, college programs, and future employment. This same report revealed that the majority of low income students

perform poorly when evaluated by the National Assessment of Educational Progress Exam, scoring 85% below their affluent peers in reading, math, and writing, and 88% below them in science. These students are becoming the Freshmen at post-secondary institutions.

Tutoring and Supplemental Services

Programs that exist in the K-12 system to assist students with deficient skills, such as after school programs, do not exist at the post-secondary level. Students must rely on skills acquired during their pre-college education or seek out tutoring for college success. According to Oesterreich (2000), research findings suggest that tutoring students at the post-secondary level plays a crucial role in the retention of all students. However, tutoring services at the post-secondary level are generally course-based and typically do not address the problems of poor reading, writing, mathematical, and critical thinking skills. Many students fail despite being provided with ongoing tutoring services. Without being equipped with adequate critical thinking skills, students are at risk in their pre-college preparation. Because this pre-college preparation is limited in the area of critical thinking skills, students may fail to reach educational and career goals.

Critical Thinking Deficiencies among College Students

Agencies such as The Education Commission for the States have begun to look at student learning beyond finances and academic preparation of students in post-secondary institutions and its relationship to future workforces in America. This new focus is on student learning in the areas of critical thinking and problem solving skills (Ewell, 2002). Students can develop critical thinking as

a result of going to college, although the degree to which this occurs may be impacted by prior educational preparedness.

Other researchers are finding similar trends in poor critical thinking skills among college students and graduates. Browne and Keeley (1988) conducted a study on the critical thinking skills of graduating college and university students and found that they lack fundamental critical thinking skills. Even when students possess adequate critical thinking skills, there is no guarantee that students will use them to find academic success. Many researchers find that students must be disposed to think critically and getting them to do so is an ongoing challenge (Halpern, 1998 and Facione, 1990). Students' deficiencies in critical thinking may also be seen in academic-related activities such as the use of technology. Post-secondary students may not be developing the level of critical thinking skills that will enable them to function in a society that is loaded with information and technology.

The Educational Testing Service (ETS) assessed 6,300 students using the Information and Communication Technology (ICT) Assessment. The ICT measures the ability to define, access, manage, integrate, evaluate, create, and communicate information in a technological environment. The November 2006 report of this assessment published by ETS reveals poor student performance in the ability to organize large amounts of information clearly and efficiently (<50%). Only a few students demonstrated key ICT skills. This research suggests that students do not possess the skills in critical thinking that enable them to perform

information management and research tasks required for academic success (ETS, 2006).

The internet is often the first place students go to research and access information. Students must come to the realization that careful scrutiny of information researched over the internet is an absolute necessity because much of it can be unreliable. Well-developed critical thinking skills are essential to determine if information is valid and verifiable. Otherwise, information gathered may be merely a product of opinion.

Educational Institutions' Accountability

In 1991, the United States Department of Education sponsored national research on the critical thinking skills of adults. The purpose of this research was to send a clear message to higher education that greater accountability regarding teaching and student learning is expected. This research also sends a message to students early in their post-secondary endeavors that there are greater expectations for them to improve their thinking ability.

According to Halpern (1993), the desire to adequately prepare students in critical thinking is not universal. Included in her report is a basic rationale for students in post-secondary institutions taking college-level courses in critical thinking. Halpern suggests that students become better thinkers when they acquire and utilize thinking skills to identify main ideas, cite evidence to support conclusions, analyze and synthesize information, and use probabilities.

The Greater Expectations Panel has made an effort to improve the standards and expectations of a quality liberal education by reporting that the

public has a critical eye on higher education and supports reviewing student outcomes and achievement as one method to achieve reform (AAC&U, 2002). To date, the Greater Expectations Panel reports that the educational community has low student expectations that will ultimately lead to a negative opinion about higher education as a whole. Rather than holding on to outdated standards, a liberal education should provide students with specific knowledge, measurable abilities and competencies such as skills in problem solving, reflection and evaluation, and critical thinking (AAC&U, 2002).

The cost of a post-secondary education is enormous and consumers want to know they are receiving the most for their money in terms of student achievement. Many post-secondary institutions are at record highs regarding yearly tuition for 2006-2007. According to Kelley (2006), the average cost per year at a four-year public college is \$5,836 and the cost per year at a four-year private college is \$30,367. George Washington University, one of the ten most expensive colleges, cost \$37,820 for the 2006-2007 academic year.

Whether or not students are getting their money's worth for a high priced post-secondary education is open to debate. Linda Wertheimer (2007) reports that the federal government wants post-secondary institutions to evaluate student progress on a regular basis and provide this data to the public who want to know if their students are benefiting from a high-priced education. Harvard University, where tuition, room and board were \$43,655 for 2006-2007, is not waiting for federal mandates to determine how well their students are performing. Harvard is

using tests of critical thinking and writing to determine if their students are learning what they need to succeed (Wertheimer, 2007).

In April 2007, the US Department of Education started working with accrediting agencies to create guidelines for post-secondary institutions to demonstrate student progress and use the information as comparison data among similar institutions. The results may become a driving force for educational reform in higher education that will ultimately benefit the students, post-secondary institutions, and the community as a whole.

The Importance of Teaching Students to Think Critically

According to the NW Regional Education Library, many scholars once thought that individuals were born with or without critical thinking abilities. However, research has shown that is not true. Not only are critical thinking skills teachable, but they are “learnable” as well (Halpern 1993).

Fisher (2001) reported that most students learn critical thinking skills indirectly through content course instruction. However, many teachers are finding this to be a less effective way of teaching students to think. They conclude that direct instruction in critical thinking is paramount to student success. If direct instruction in critical thinking results in improved academic achievement as well as improved critical thinking skills, it may lend support for supplemental instruction in these skills as a means of retaining students.

Stern (2001) cites supplemental instruction in critical thinking and abstract reasoning skills as one of the tools to improve student learning outcomes at all levels. Halpern (1993) warns that gains in critical thinking are gradual. Therefore,

it would be unrealistic to expect huge gains in post-secondary students' critical thinking abilities based on one course and even less attributable to a course that is given early in students' undergraduate education due to the expected cognitive growth throughout the undergraduate educational experience of most students. Ultimately, the goals are to improve critical thinking skills and the level at which students utilize these skills outside the classroom where an instructor is not present to prompt them to draw on skills learned (Halpern, 1993). Whether learned skills decrease over time is still a topic for debate. However, research suggests that critical thinking skills courses have shown positive effects that are transferable to a wide variety of situations.

According to Tsui (1999), the focus on knowledge building through content coverage comes at the neglect of building the essential skills of how to think. Four-year institutions may be undecided about how best to address this goal of enhancing critical thinking skills among college students, but two year institutions and community colleges aren't waiting to figure it out. Elder (2000) reports that every fall, 5.6 million students choose two-year colleges because of the opportunity to gain skills and abilities necessary for employment. Robert Reich, former United States Secretary of Labor, has pointed out that students must be able to think in ways not only not yet emphasized in most present instruction, but in ways that are unpredictable. Higher order thinking required in successful workers of the future is described as "disciplined reasoning that directs and redirects thinking along a problem-solving path, clarifying and checking itself as it goes" (Elder, 2000).

The Debate over How to Teach Students to Think Critically

There is a general expectation at the post-secondary level that students entering college know how to reason and think critically. Unfortunately, university retention data suggest this expectation is not always realized. In 1988, the Educational Resources Information Center (ERIC) published a report about the necessity of teaching critical thinking skills such as reasoning and problem solving to students separate from any particular discipline so that students could learn to apply these skills across their curriculum (ERIC Digests, 1988).

The Christian Science Monitor's report (2003) on thinking highlighted the research of Patricia King from the University of Michigan that focused on reflective judgment and higher order thinking skills of undergraduates. King's research revealed that many students increase these skills as a direct result of attending college. However, most reach only low levels of these skills by graduation. Her research reported that seniors are able to understand and approach problems from different perspectives, but are still unable to achieve reasonable conclusions to problems, even when all relevant facts are available.

Research studies have addressed the issue of improving critical thinking skills among post-secondary students, particularly with students studying for professional careers such as nursing, law, medicine, and teaching. Nursing and medical students were better able to make treatment decisions related to patient care following instruction in critical thinking (Niedringhaus, 2001). Byer (1986) reported that post-secondary students enrolled in teacher preparation programs that emphasized critical thinking made impressive gains. These gains were

attributed to a transformation on the part of instruction that made a shift from memorization to critical thinking and reasoning in decision making.

While theorists continue to debate the most effective methods of teaching critical thinking skills, students whose critical thinking skills are not adequate may be affected in many ways. Many are required to repeat courses and delay degree completion. Course repetition is problematic for students on many levels resulting in financial hardships, academic probation and dismissal, transfers to other universities, or loss of an intended major or career.

According to Glaser (1984), educational systems have in some ways failed students because of theoretical approaches that teach basic skills without encouraging them to think. The debate about how critical thinking skills should be taught to think critically continues. According to the Delphi Report (Facione, 1990), the following points are a few components the Delphi Project offers regarding the instruction and assessment of critical thinking skills:

1. Judging when one is or is not performing well
2. Considering ways to improve one's performance
3. Knowing what procedures to use and when to use them
4. Explicit instruction in the use of procedures to improve critical thinking

Organizations such as the US Department of Education and the US Congress demand gains in the critical thinking skills of post-secondary students. However, this requires considerable research into the alternatives. Instruction at the post-secondary level is predominantly delivered by professors who are experts in their fields of discipline. While professors have advanced training in

their areas of expertise, very little, if any of their training includes formal training in the fundamentals of teaching, adult learning or how to teach students to transfer information and learning (Halpern, Hakel, & Milton, 2003).

One of the most effective ways of teaching critical thinking may be to consider Vygotsky's (1962) claim that learners should be viewed as active creators of their own thought. Researcher Valerie Wilson (2000) theorizes that interventions to improve thinking may be more effective while the brain is still undergoing development in childhood rather than waiting until it is fully developed. Wilson (2000) concluded:

There appears to be a two-way relationship between the working of the cerebrum and the tasks upon which it is engaged: while the connections within it are necessary for higher level activities to be undertaken, those connections also develop if stimulated.

These claims suggest that teachers may also play an active role in fostering the critical thinking skills of their students. According to Wilson (2000), the brain can be portrayed in the following ways as it relates to higher order thinking and learning of human beings:

- Brains are portrayed as under-used and, therefore, capable of further development.
- Learning is seen as requiring active participation by learners in a social environment.
- Learners must be supported by teachers (Vygotsky's scaffolding) who should gradually extend the learning challenges for their students.

The research of Wilson (2000) and others leads to serious questions about whether faculty are prepared to meet the demands of governmental agencies to improve the critical thinking skills of students at the post-secondary level. In a study conducted by Brown and Keely (1988) faculty were surveyed regarding their teaching performance with 90 percent reporting above-average or superior performance. However, a study by Travis (1995) revealed that many college professors have not been prepared for teaching at the post-secondary level. According to Browne, Neil, Meuti, and Michael, (1999), the majority of faculty engage in activities to attain expert knowledge in their field rather than efforts to convey that knowledge. In most cases, faculty teach in the manner in which they were taught that included frequent expository lectures that lacked opportunities for students to engage in critical thinking practices or active learning (Browne, Neil, Meuti, and Michael, 1999).

There are researchers who believe that critical thinking instruction should be explicit and delivered in a course or disciplined fashion through course specific content or through a course in critical thinking. Glaser (1984) is one of the researchers whose studies revealed that students could improve critical thinking in this manner. Yet there are researchers such as McPeck (1981), and others who believe critical thinking taught outside a particular discipline does not constitute critical thinking. Still, there are other researchers such as Halpern (1993) who believe that students can be taught to transfer skills across domains and thus apply critical thinking skills to learning outside a particular discipline.

The concept of general thinking and reasoning skills that transcend specific academic disciplines was the subject of a research study conducted by Marzano (1998) at the Mid-continent Regional Educational Laboratory (McREL) located in Colorado where researchers reviewed national standards in the academic disciplines. The purpose of their review was to determine if general reasoning and problem solving skills were expectations in the standards for each academic discipline reviewed. Results of their study revealed that general reasoning and problem solving were standards expected across several disciplines, a conclusion that suggests that students can benefit from instruction in these skills to apply across their curricula.

According to Hanley (1995), students must learn to become skilled in critical thinking but also just as skilled in determining which skills to employ in various situations requiring expertise in critical thinking. In order for students to develop excellence in critical thinking, Hanley (1995) believed students must first develop excellence in both cognitive and metacognitive skills; the focus of a critical thinking skills course in his study to promote the development of these skills. The cognitive skills for Hanley's study were identified as strategies used to encode, transform, organize, integrate, score, categorize, and retrieve information, while the metacognitive skills were those used to control and monitor one's knowledge (Hanley, 1995).

Students were asked to assess their thinking and problem-solving ability prior to and following lessons on problem-solving and decision-making and determine which cognitive and metacognitive skills were necessary to

successfully complete the problems (Hanley, 1995). Critical thinking and metacognitive approaches employed by above and below average students were compared. The results of Hanley's study provided insights into teaching critical thinking to students. Results revealed a disparity between what students thought they learned and their grades that did not reflect what they learned. Students gained an increased awareness of how their cognitive processes influence their approach to learning and their need to know what to do and not to do when approaching problems (Hanley, 1995).

A recent study by Hatcher (2006) revealed that an integrated approach to teaching critical thinking to students at the post-secondary level may be more successful than any single course in critical thinking or logic because of the opportunity for professors in many disciplines to enhance the critical thinking skills of their students through the course of instruction. John McPeck (1981) reports strong opinions against teaching critical thinking outside a particular discipline. In many ways, single or stand alone courses in critical thinking ignore what many researchers consider general critical thinking skills that transcend any particular discipline, thus supporting the superiority of an integrated approach to teaching critical thinking (Hatcher, 2006).

Despite the claims of researchers for or against teaching critical thinking to students in course specific content, there continue to be researchers who find positive gains in the critical thinking skills of students when instruction is delivered in this manner or through a specific skill area. Quidamo (2007) conducted a study to determine if writing could significantly affect overall critical

thinking skills in the core cognitive skills of critical thinking such as analysis, evaluation, and inference assessed by the CCTST. Quidamo (2007) found that writing did significantly impact critical thinking and core cognitive skills. Other researchers have shown significant improvement based on course specific instruction in the review of historical documents (Reed, 1998), the evaluation of drug literature by pharmacy students (Miller, 2004), in psychology (Haloen, 1995), biology (Chaplin, 2007) and general liberal arts courses (McPeck, 1984).

Chaplin (2007) conducted a study with at-risk first year students in biology courses to determine if modeling and coaching would be a significant factor in their ability to improve higher order thinking and metacognitive skills. Students demonstrated poor study habits, time management and organization skills. Poor performing students did not realize their weaknesses or gaps in knowledge, and had no idea how to improve their studying and metacognitive skills to improve their performance. When students were coached, they were better able to recognize levels of critical thinking appropriate for questions and better able to pinpoint areas for future studying (Chaplin, 2007).

Finally, Halpern (1999) developed a four-part model of critical thinking that she reports achieves the following:

1. instructs students in the skills associated with critical thinking,
2. instructs students on the dispositions associated with critical thinking,
3. provides structural training to help students recognize when a particular skill is needed and create cues to retrieve and recall thinking skills on demand, and

4. instructs students in meta-cognitive monitoring to help them remain cognizant of their knowledge while monitoring it.

Halpern, Hakel, and Milton (2003) remind those working with students that long-term transfer of learning is essential to student success. Students must learn to develop cues to retrieve information to prepare them for the demands of critical thinking. To do so, students must have ample opportunities to practice these skills under variable conditions to achieve better learning (Halpern, et. al, 2003).

Cognitive and Affective Skills Associated with Critical Thinking

In 1988, a group of experts in the instruction and assessment of critical thinking utilized the Delphi Method to form an interactive panel to discuss the cognitive skills and affective dispositions related to critical thinking (Facione, 1990). The Delphi Project of 1990 was the result of almost two years of research on critical thinking conducted by the panel. The Delphi Project panel initiated their analysis of critical thinking by identifying six cognitive elements of critical thinking expected of both freshman and sophomore post-secondary students; (1) Interpretation, (2) analysis, (3) evaluation, (4) inference, (5) explanation, and (6) self-regulation that are considered the core elements of critical thinking (Facione,1990).

Another finding of the Delphi Project clearly indicates that improvement of critical thinking skills comes from all facets of an individual's life, such as self-evaluation of one's own critical thinking and reasoning processes, increasing life experiences, and engaging in program specific learning that fosters the

development of critical thinking skills rather than learning a specific body of knowledge or list of logical operations to follow (Facione, 1990).

The Delphi Report revealed dispositional components of critical thinking that can be correlated with one's cognitive disposition to think critically (Facione, 1990). From a metaphorical standpoint, the Delphi experts describe good critical thinkers as those who demonstrate probing inquisitiveness, keenness of mind, zealous dedication to reason, and hunger or eagerness for reliable information. Weak critical thinkers do not demonstrate these skills (Facione, 1990).

The Goals 2000 Educate America Act, put into law by the United States Congress in 1990, stipulates expectations for the improvement of critical thinking skills among college students. According to the United States Department of Education (1991) the goal states the following:

The proportion of college graduates who demonstrate an advanced ability to think critically, communicate effectively, and solve problems will increase substantially.

Unfortunately, many years later not much changed in the improvement of critical thinking skills of college students. Robert Ennis (1995) who is a well-known leader in the critical thinking movement offered the following:

Although critical thinking has often been a goal of education throughout most of this century, not a great deal has been done about it.

Assessment of Critical Thinking Skills

Leading researchers of critical thinking such as Ennis (1990), Halpern (1993), Paul and Nosich (1991), and Facione (1990) report that a first step in the

assessment of critical thinking must start with a clear goal for the assessment of critical thinking, a comprehensive definition of critical thinking, and the use of various measure of critical thinking (Spicer & Hanks, 1995).

According to Jones et. al (1995), whose findings are the result of numerous studies to define critical thinking, there is no comprehensive test that assesses all aspects of critical thinking. The definition of critical thinking established by Jones et. al (1995) considers seven facets of critical thinking such as: 1) interpretation, 2) analysis, 3) evaluation, 4) inference, 5) presenting arguments, 6) reflections, and 7) dispositions. Within each of these skill categories are sub-skills that define critical thinking (NPEC, 2000).

The assessment of students' critical thinking skills at the post-secondary level has been undertaken by numerous researchers. According to Ennis (1993) there is no comprehensive test of critical thinking. Those who tackle the challenge of assessing the critical thinking skills of students may fall into several traps because of the style of assessment used. Ennis (1993) identified several points related to those traps that deserve mentioning here:

1. Caution should be undertaken in comparing test results to norms and claiming that a difference or similarity in results is due to instruction when it may be related solely to the influences of the subject group.
2. A second trap is giving pre- and post- tests without a control group, which makes the results questionable.
3. Giving the same pre- and post- test may alert students into the questions and the intent of the test. However, Ennis cautions those who are

opposed to using a different test as a post-test because it is indeed a different test.

4. Caution should be taken in giving only multiple choice tests because they miss important aspects of critical thinking that cannot be assessed using multiple choice questions alone.
5. Multiple choice questions may be legitimately answered differently by the test taker because of the differences in background, assumptions, and beliefs of the test creator.
6. Those assessing critical thinking should recognize that significant changes in the critical thinking skills of those being evaluated take a long time, where as, intervention times are often too short to result in a noticeable difference.

There are numerous assessment measures of critical thinking. However, the United States Department of Education, in its 2000 National Postsecondary Education Cooperative (NPEC) report, chose 12 tests for review because of their ability to measure critical thinking and/or the dispositions of college students. This researcher obtained permission from the US Department of Education to cite the tests used in their 2000 NPEC Assessment Volume 1 report. The critical thinking assessment measures reviewed were as follows:

1. Academic Profile (A. Profile)
2. Collegiate Assessment of Academic Proficiency (CAAP)
3. California Critical Thinking Dispositions Inventory (CCTDI)
4. CAAP Critical Thinking Assessment Inventory

5. California Critical Thinking Skills Test (CCTST)
6. Cornell Critical Thinking Test (CCTT)
7. College Outcomes Measures Program – Objective Test (COMP)
8. ETS Tasks in Critical Thinking (ETS TASKS)
9. Measure of Intellectual Development (MID)
10. Problem Solving Inventory (PSI)
11. Reflective Judgment Inventory (RJI)
12. Watson-Glaser Critical Thinking Appraisal (WGCTA)

Several additional critical thinking assessments are widely used for post-secondary students. These additional tests were compiled by Robert Ennis (1999) who is a leader in critical thinking. Five of the tests listed by Ennis were not included in the NPEC 2000 review, but are mentioned here because they assess one or more aspects of critical thinking. They are as follows:

1. Ennis-Weir Critical Thinking Essay
2. Assessment of Reasoning and Communication
3. Critical Thinking
4. Critical Thinking Interview
5. Critical Thinking Test

The California Critical Thinking Skills Test was the assessment measure used in numerous studies to assess the critical thinking skills of post-secondary students (Facione, 1991; Stein, et. al 2003; Miller, 2004; & Harrell, 2004), most of whom used Forms A and B of the CCTST. However, an updated form of the CCTST includes Form 2000, which is considered by Insight Assessment to be a

more robust form of the CCTST Form A that includes more contemporary questions and includes charts and graphs for evaluation (Insight Assessment, 2002). The CCTST is a 34-item test that assesses core cognitive skills such as analysis, evaluation, and inference, as well as scores in inductive and deductive reasoning and an overall total score. The CCTST takes approximately 45 minutes to complete.

Research studies aimed at the improvement of critical thinking skills of post-secondary students have employed the use of the CCTST to assess the improvement of students' critical thinking skills following critical thinking skills instruction in course specific and non-course specific experiments. Facione (1991) researched the effects of a critical thinking skills course among college students and found that scores on the CCTST showed greater acquisition of critical thinking skills for male students than female students, significant differences in the level of critical thinking skills based on post-testing depending on students' major, and a strong positive correlation with grades.

Research in assessing the critical thinking skills of nursing students is abundant and includes studies such as the study conducted by Deborah Becker (2007) in which the CCTST was used to assess the effect of instructional methods on nurses' critical thinking skills. Becker 's (2007) study emphasized the necessity to teach nurses to think critically through patient simulation due to the inability to teach students about all situations that may arise during their practices.

Soukup (1999) used the CCTST to evaluate gains in critical thinking skills of nursing students during their studies for an associate's degree in nursing. Critical thinking is considered essential to the nursing profession because students are expected to draw from their background knowledge and apply that knowledge to situations that arise with their patients. The results of the study focused on the change in total score and the core cognitive elements: analysis, evaluation, and inference as well as deductive and inductive reasoning.

Phillips, Chesnut, and Rospond (2004) conducted a study using the CCTST and the California Critical Thinking Disposition Inventory (CCTDI) to assess the critical thinking and dispositions toward critical thinking of pharmacy students. The purpose of that study was to determine if curricular changes were needed to ensure that their future pharmacists possessed thinking strategies that would enable them to acquire, analyze, and synthesize knowledge and information. According to Phillips et. al (2004), the Accreditation Council for Pharmaceutical Education sets guidelines for educational institutions and expects institutions to foster critical thinking and problem solving skills in pharmacy students and build assessment measures of critical thinking into its accreditation process.

Research conducted by Miller (2004) examined the research evaluation skills of pharmacy students in an effort to determine if the CCTST was a predictor of the ability of the students to evaluate in an expert manner. Even though the results of Miller's research revealed that the CCTST was not a predictor of expert evaluation ability among students or their ability to apply their skills in pharmacy

courses, the study did reveal that the CCTST is correlated with course grade and final exam grade suggesting it is a predictor of course performance in general (Miller, 2004).

Research studies conducted by leading researchers who have employed the use of Form 2000 of the CCTST are currently available in published form (Facione, 1990; Douglas, 2006; & Becker, 2007). In a recent study conducted by Douglas (2006), Form 2000 of the CCTST was used to assess the critical thinking skills of undergraduate and graduate engineering students. The results of that study provided insight into the factor of time and total score. Douglas (2006) found that graduate students did not on average finish all of the questions in the 45 minute time allowance on the CCTST and subsequently performed less well than the undergraduate students who guessed on questions they did not have time to complete. The results of Douglas' 2006 study may provide insight into the differences in thinking abilities of comparison groups and how they approach tasks in critical thinking. These results may ultimately provide curricula changes needed to foster and enhance the critical thinking skills of post-secondary students through the incorporation of instructional techniques developed from this and future research into how students approach critical thinking.

Gadzella (2002) used the critical thinking scores of the Watson Glaser critical thinking skills test (WGCTA) to predict grade point averages of students majoring in Education. However, Gadzella's (2002) found only a small variance in grade point average based on the WGCTA.

The Halstead-Reitan Category Test (HCT) is a major component of the Halstead-Reitan Neuropsychological Test Battery. The HCT was developed by Ward Halstead and used in research in the 1940's. Through factor analysis, Halstead found the Category Test to be the best fit for the label of 'Abstraction' and summarized it as follows:

This factor concerns a basic capacity to group to a criterion, as in the elaboration of categories, and involves the comprehension of essential similarities and differences. It is the fundamental growth principle of the ego (DeFilippis, 2002).

According to DeFilippis (2002), Halstead reported the fundamental growth principle of the ego as a process of learning by which individuals develop sets and frames of reference to approach new and unfamiliar stimuli. The Halstead Category Test is integral to the Halstead-Reitan Neuropsychological Test Battery and has been described as the most useful and sensitive test in discriminating brain damaged patients from those whose neurological symptoms are less well defined and also serves for comparison purposes with these populations and normal individuals. Shute and Huertas (1990) described the Category Test as a measure of Piaget's formal operations stage that is considered the stage in which individuals are able to reason and problem solve at the highest level. Shute and Huertas (1990) reported that approximately 50% of normal individuals fully reach this stage of cognitive development, which may explain the variability in total error scores among sample populations including those composed of college students. Detailed information on the Category Test can be found in Chapter 3.

Methods to Improve Critical Thinking Skills of College Students

Thinker's Guides

Richard Paul and Linda Elder are two leading researchers in critical thinking. Paul and Elder have taken the core elements of critical thinking and the characteristics of good critical thinkers from prior research, including the Delphi Report, and expanded upon them to address the critical thinking needs of students at all levels. They developed a series of tools entitled “The Thinker’s Guides” to teach critical thinking skills at the post-secondary level. The guides address the following:

Critical Thinking Concepts and Tools	The Human Mind
How to Study & Learn a Discipline	Critical & Creative Thinking
The Art of Asking Essential Questions	Analytic Thinking
Active & Cooperative Learning	Scientific Thinking
How to Improve Student Learning	How to Read a Paragraph
How to Write a Paragraph	Ethical Reasoning
Fallacies: The Art of Mental Trickery & Manipulation	

The Thinkers Guides identify general concepts related to critical thinking and specific critical thinking skills necessary to think effectively for different disciplines and tasks. The Thinker’s Guides are based on Richard Paul’s model of critical thinking that has three main components that include elements of thought/reasoning, intellectual standards and intellectual traits. Paul and Elder contend that this model of critical thinking can meet the challenge of many demands of reasoning (Paul & Elder, 2006).

The metacognitive approach imbedded in Paul's definition of critical thinking is the basis underlying the development of the Thinker's Guides. The guides utilize metacognition to encourage students to look at the intricacies of thought, including the pitfalls. Paul and Elder provide crucial information in each of the guides to move students through a systematic approach from superficial and ego-centric thinking to skilled analytical and reflective thinking.

There are three main components of Paul's model of critical thinking. Figure 4 illustrates the first component, elements of thought/reasoning. The second component of Paul's model of critical thinking is the notion of Universal Intellectual Standards by which all thinking should be assessed (Paul and Elder, 2005). Figure 5, illustrates the Intellectual Standards that are central to his model of critical thinking. Paul and Elder (2005) found that excellence in thought requires intellectual traits and attributes that comprise the third component of the model of critical thinking. (See Figure 6)

Figure 7 is an illustration of how good critical thinkers engage in critical thinking. Good critical thinkers apply intellectual standards on elements of thought as they develop intellectual traits (Paul & Elder 2006).

Rationale Argument Mapping Program

Rationale is a critical thinking skills program developed by Tim van Gelder that claims to achieve significant gains in critical thinking skills among undergraduate students. Rationale uses argument maps that are computer-generated allowing for an interactive approach that builds and evaluates students' arguments. The program provides guidance in developing arguments,

scaffolding, feedback, and motivation to transfer and use critical thinking skills. Reason! is a supplemental program that provides a practice environment for students. Rationale and Reason! have been used for undergraduate students who were pre- and post- tested using the California Critical Thinking Skills Test. They have been shown to improve critical thinking skills by approximately one standard deviation when compared to other direct methods of teaching critical thinking skills (van Gelder, 2001). Twardy (2003) used Rationale to study the effects of argument mapping on students' critical thinking skills. The results of Twardy's (2003) study revealed that students who analyzed arguments using argument mapping showed three times the improvement in critical thinking skills based on pre- and post- testing with the CCTST.

Rationale is a tool that can be used to diagram reasoning on any topic and supports rapid viewing, sharing, and building of those diagrams (van Gelder, 2007). Rationale is interactive and provides students with a visual map of reasoning and evidence for and against a statement. Through a series of shapes that hold propositions, relationships between them and evidence of reasoning for or against a proposition are the essence of Rationale. According to Austhink (2007), not all maps are argument maps and some maps may simply depict a relationship such as a hierarchical relationship typically viewed in pyramid or grouping form (van Gelder, 2007). The crucial element of an argument map is that it is driven by the question "why should I believe that?" followed by supportive evidence and reasoning.

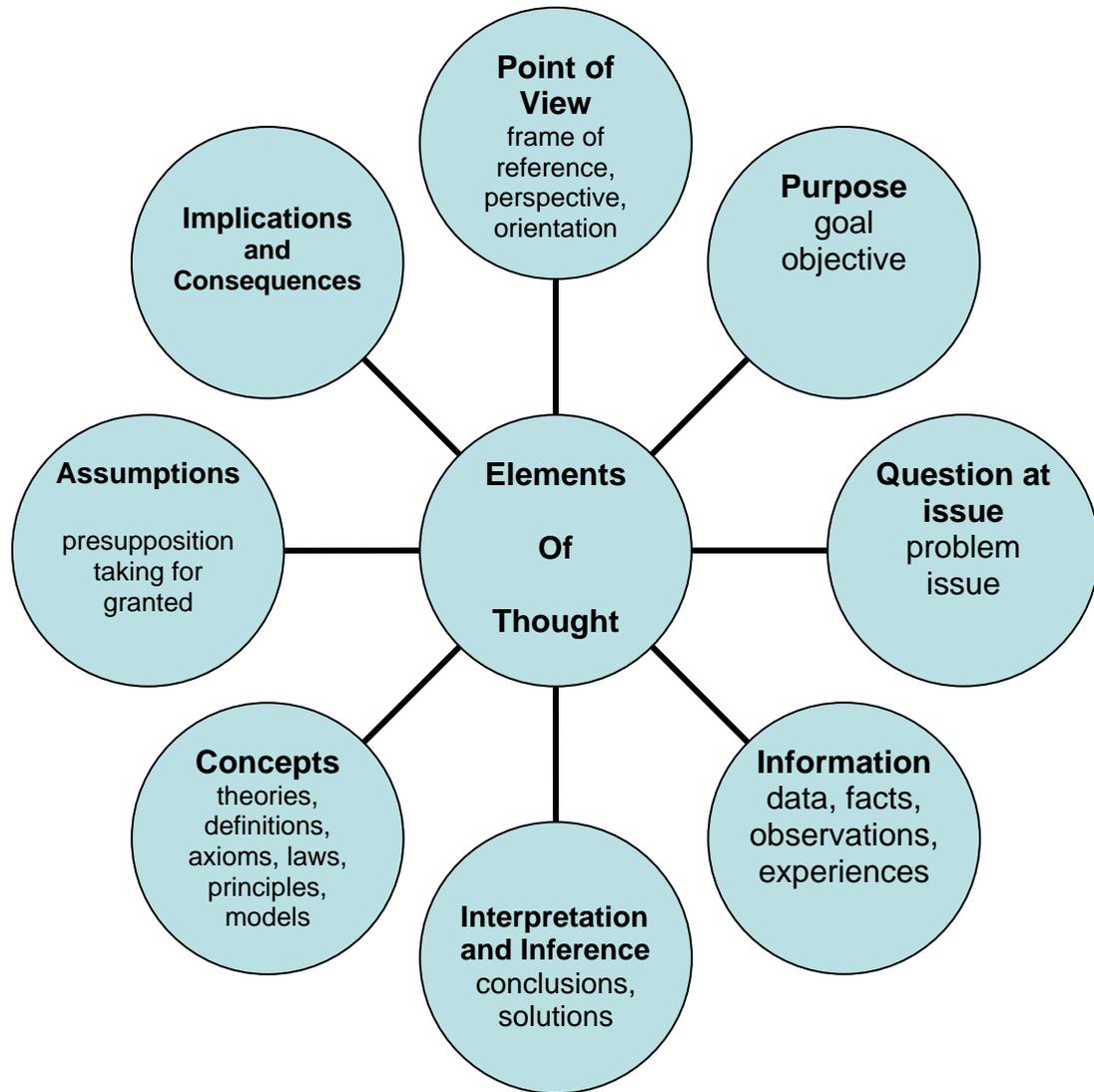


Figure 4. An illustration of the Elements of Thought of Paul's Model of Critical Thinking adapted from A Guide to Educators to Critical Thinking Competency Standards, Paul and Elder (2005), Foundation for Critical Thinking.

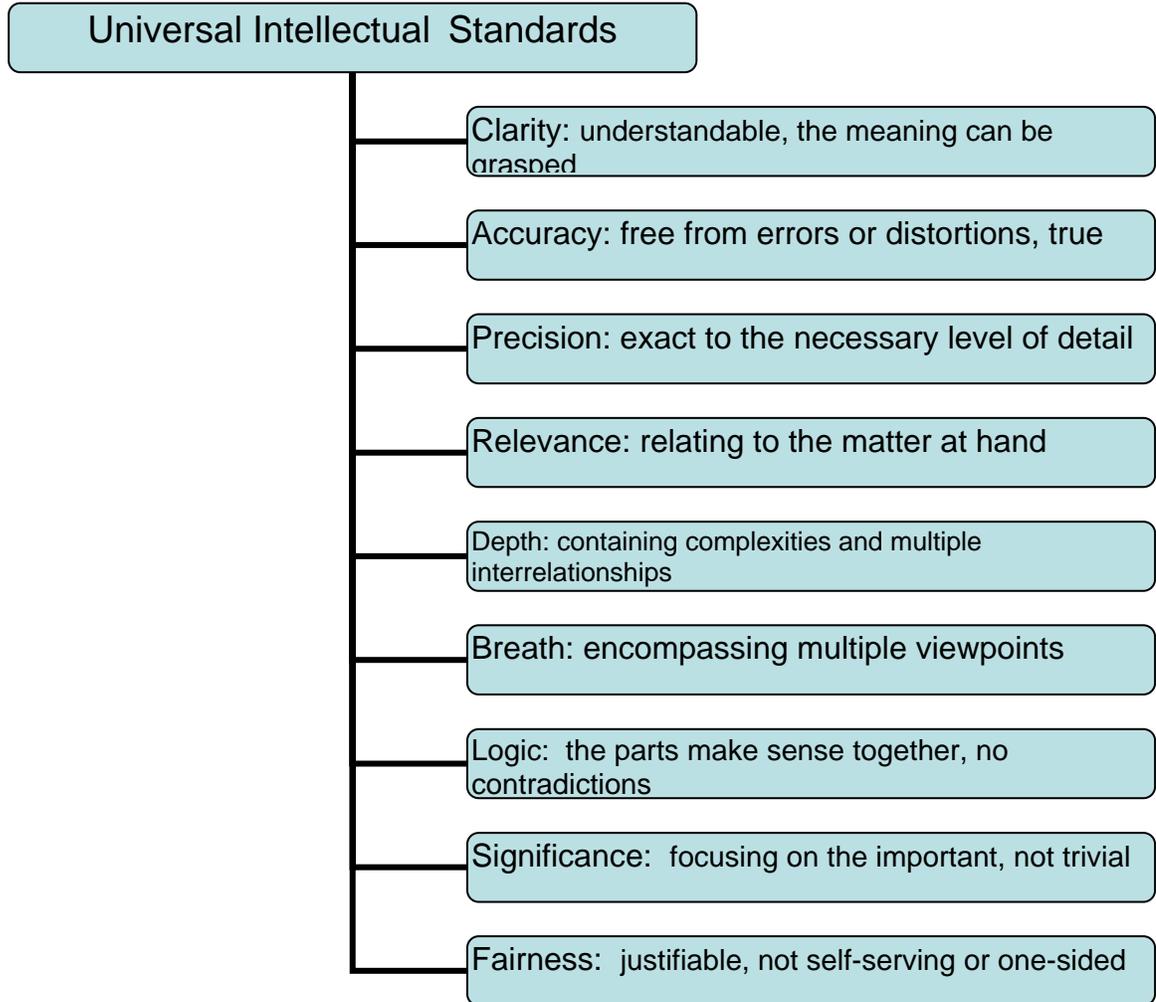


Figure 5. An illustration of the Universal Intellectual Standards from Paul's Model of Critical Thinking adapted from *The Miniature Guide to Critical Thinking Concepts & Tools*, Paul and Elder (2006), Foundation for Critical Thinking.

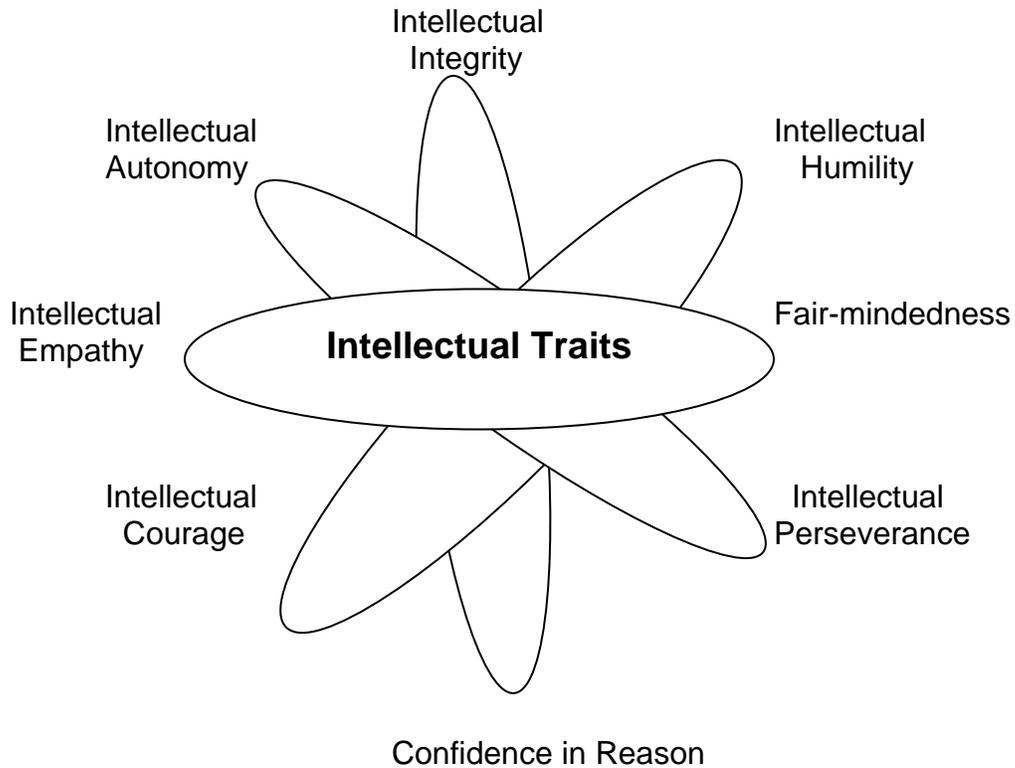


Figure 6: An illustration of the intellectual traits of Paul's Model of Critical Thinking adapted from A Guide to Educators to Critical Thinking Competency Standards, Paul and Elder (2005), Foundation for Critical Thinking.

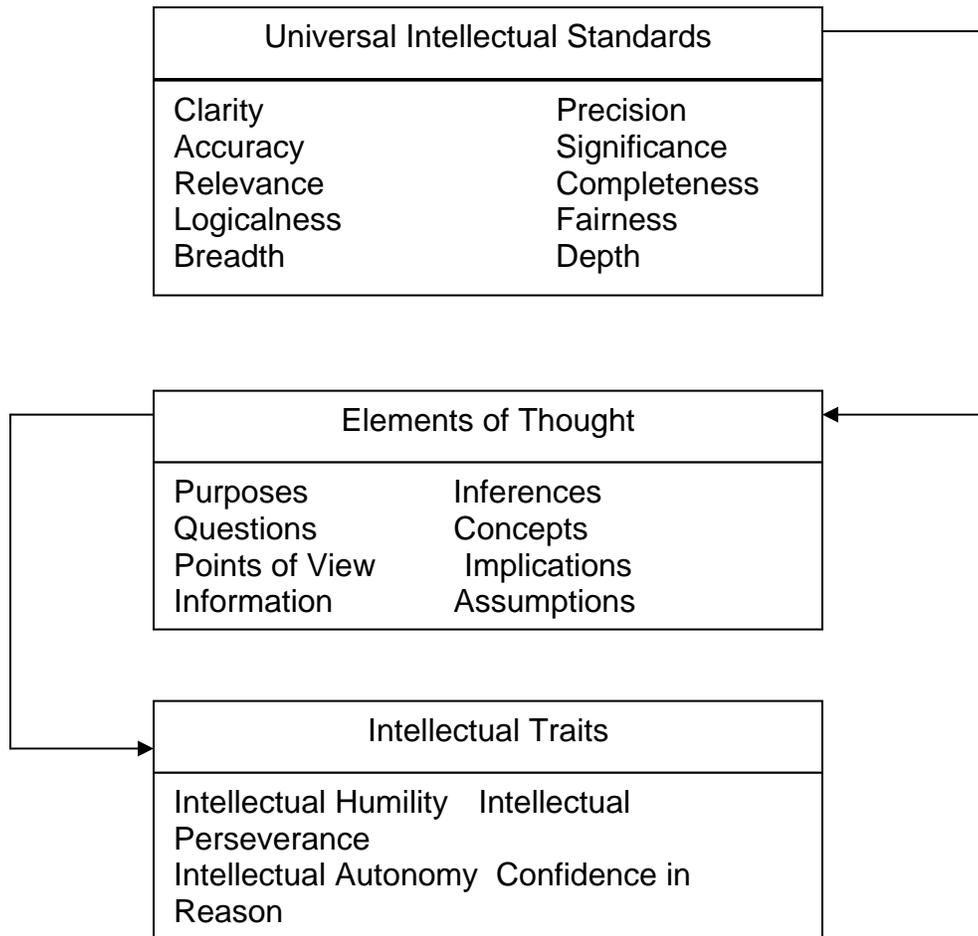


Figure 7. An illustration of how critical thinkers apply universal intellectual standards on elements of thought as they develop intellectual traits. Adapted from A Guide to Educators to Critical Thinking Competency Standards, Paul and Elder (2005), Foundation for Critical Thinking.

Rationale argument maps consist of box and line diagrams created by a student or student group whose goal is to clarify and organize thinking by showing the logical relationships between thoughts that are expressed simply and precisely (Austhink, 2007). Each argument map's construction is based on two simple questions of why or why not one should believe a statement. Thus, the beginning map starts with a contention or main claim that should be accepted or rejected. The next task is for students to begin building a map that consists of layers of reasoning written inside figures that are for or against the reasoning that is directly above it. This is done in a scaffolding manner by providing support or objection for the reasoning in each figure. Reasoning in support of a claim is highlighted in green while reasoning that is in objection to a claim is highlighted in red. Students continue building the argument map by providing reasons or evidence to accept or reject a contention (Austhink, 2007). Rationale can be used to produce reasoning maps that can be done in a quick and intuitive way or analytic maps that require more scrutiny and analysis (Austhink, 2007).

Figure 8 illustrates an argument map using the Rationale program. The reasoning map shown in Figure 8 is a basic map that can be done in a short period of time. Figure 9 illustrates an example of an analytic map created by the Rationale program. The analytic map requires on-going analysis and requires much longer to complete. The analytic map is more detailed and illustrates an abstract claim in the upper portion of the map and shows how reasoning that supports or opposes the claim in lower cells of the map.



Figure 8: Basic Argument Map from Austhink www.austhink.com .

One of the unique features of Rationale is that it allows one to visualize one's reasoning, pinpoint errors in reasoning, poor evidence or lack of support, and ultimately modify the reasoning process. The interactive components of Rationale allow one to zoom in and pan around cells and also change the layout of the maps for a particular feature of reasoning (van Gelder, 2007). Another distinct feature of Rationale is that it allows overlays to be placed over the shapes or “infons”, a term created by Austhink to hold information, to help one uncover strengths and weakness in arguments (van Gelder, 2007).

Rationale, formerly known as Reason!Able was developed to improve the reasoning and critical thinking skills of undergraduate students. Reason!Able developed from what is also known as the Reason Project in which the underlying idea was that students should improve critical thinking and reasoning skills with repeated practice (van Gelder, 2007). According to van Gelder (2007), factors related to the improvement of reasoning and critical thinking are still being

uncovered. However, the themes of usability, complementation, and semi-informality may in part explain how Rationale is helping individuals improve their reasoning and critical thinking skills (van Gelder, 2007).

van Gelder (2007) refers to the usability of Rationale as a tool to help individuals engage in reasoning activities in an effective and efficient manner by doing the following:

- Rationale is designed to support cognitive activities.
- Rationale can be represented in a spatial manner through symbolic structural markers, lines, position in space, shapes, colors, etc. to maximize communication, representation, manipulation, and evaluation
- Rationale allows one to modify the layout of an argument map to reveal some aspect of reasoning in an effective manner.
- Rationale also allows one to de-emphasize any portion of an argument map by making it transparent, but still present in the map.

According to van Gelder (2007) complementation as a second theme in Rationale refers to how the program can be used to complement the human mind's strengths and weaknesses by doing the following:

- Rationale provides a mechanism by which the range of human short-term memory can be augmented through chunks of information through meaningful grouping.
- Rationale allows one to create and modify representations and access information upon demand more quickly than traditional methods by

using the visual representations of lines, arrows, shapes, and positions in space.

According to van Gelder (2007), the third theme of Rationale is one that moves typical informal thinking to semi-formal by doing the following:

- Expecting a high level of explicitness and rigor
- Claims must be presented in a discrete and grammatically correct fashion.
- Material with no direct connection to reasoning must be eliminated.

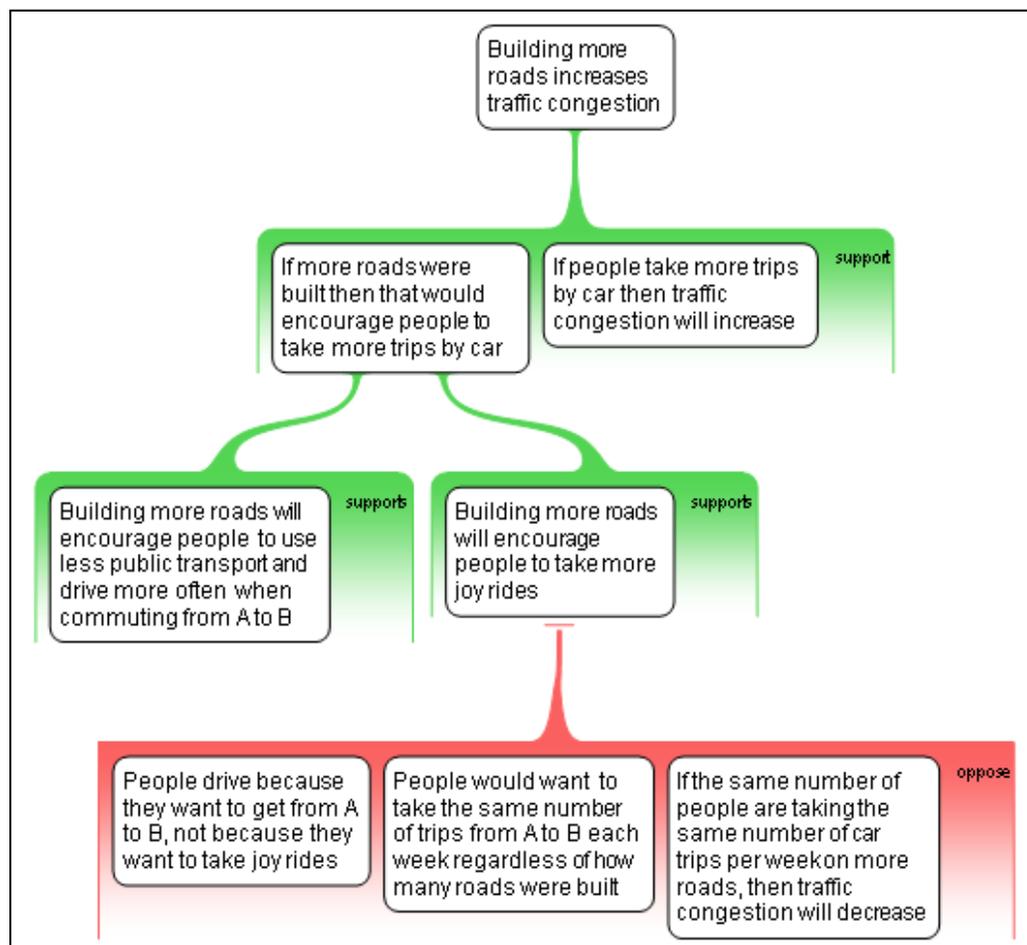


Figure 9: An illustration of a Rationale map taken from Wikipedia, the Free Encyclopedia. http://en.wikipedia.org/wiki/Argument_map .

- Central contentions or disputes must be specified.
- All direct evidential links between claims must be specified.
- All unstated claims or assumptions must be identified and specifically stated.
- All activities can be scaffolded for a visual representation.
- Abstract claims should be at the top, with more concrete claims below.
- Introduces formality and acknowledges its limitations while maintaining informal dimensions

Summary of Literature

The need to improve the critical thinking skills of post-secondary students has been well established. Despite modern efforts to define critical thinking, there appears to be no one definition of critical thinking that is acceptable to current leaders in the critical thinking movement. It appears that critical thinking is so multi-faceted that one definition is simply insufficient. Researchers continue to refine the concept of critical thinking. Unfortunately, the lack of a general consensus on the definition of critical thinking hampers the efforts of researchers to develop a comprehensive assessment tool of critical thinking. Despite the fact that there are numerous assessment tools of critical thinking, there is no test that assesses all aspects of critical thinking defined by experts in the field.

Strategies regarding the best method to improve the critical thinking skills of students continue to be compared and debated. There are a plethora of research studies addressing these instructional strategies that show success when delivered through course specific content and through critical thinking

courses alone. Students must not only have opportunities to learn critical thinking skills, but have opportunities to practice and transfer these skills. However, for struggling learners who enter post-secondary institutions each year, the challenge to keep their heads above water with expectations to perform well in an environment that demands well developed critical thinking skills is enormous.

Students are often products of a pre-college environment that does not adequately prepare them to think or provide opportunities to develop critical thinking skills. This may be in response to government legislation to improve students' test scores in reading, mathematics and science, but at the cost of teaching students to develop the higher order thinking skills that will enable them to become independent thinkers rather than students who think concretely and those who merely regurgitate facts and figures.

Government legislation is beginning to demonstrate greater demands for educational accountability among institutions of higher education to produce graduates who can meet the demands of the workforce that now focus on the ability of employees to think critically. Unfortunately, despite government legislation, institutions of higher learning are slowly addressing the issue of improved critical thinking skills of its students. Institutional efforts to improve the critical thinking skills of post-secondary students may not be addressed quickly enough to ensure that graduating students possess the skills they need to meet workforce demands and to compete with their peers worldwide.

Based on a review of the research, the definition of critical thinking developed by the Delphi Panel of 1990 was the definition used for this study.

Several methods of intervening to improve the critical thinking skills of post-secondary students have been reviewed here. Two methods were chosen because of their ability to address the cognitive skills of critical thinking as well as their ability to provide essential practice of skills learned. The Thinker's Guides developed by Richard Paul and Linda Elder through the Foundation of Critical Thinking and the Rationale computer argument mapping program developed by Tim van Gelder through Austhink were chosen.

Through direct instruction using the Thinker's Guides, it was hypothesized that students would improve their critical thinking skills because they were taught depth of reasoning, intellectual standards and intellectual traits. Through the use of the Rationale program, it was expected that students would improve their critical thinking skills and demonstrate improvement through argument mapping. Students were expected to generate more complex maps as they improve in critical thinking. Both experimental groups of students were expected to show greater improvement in critical thinking skills and final grades than students in the control group who received tutoring alone.

CHAPTER THREE

METHODS

Introduction

There have been decades of numerous research studies on critical thinking and the failure of post-secondary institutions' ability to produce graduates who think critically. However, there have been a limited number of studies that demonstrate the use of critical thinking programs and their ability to improve the critical thinking skills of students. This lack of research may be due to the lack of agreement on whether students should be taught through stand alone courses in critical thinking or taught critical thinking as an integral component of specific disciplines. Research also suggests that content course tutoring is crucial to student success, but tutoring alone may not guarantee success.

The purpose of this research study was to evaluate two critical thinking skills interventions, The Thinker's Guides and Rationale Argument Mapping Program, to determine if direct instruction in these programs, in addition to content course tutoring, would improve the critical thinking skills and academic achievement of freshman students who were repeating courses. A sample of 78 freshman students was randomly assigned to two experimental groups or a control group. Each student was assigned an individual tutor for the repeated course. Students in the experimental groups were expected to achieve higher levels of critical thinking and academic achievement than those in the control group.

Design

The design for this study was an experimental pre-test, post-test randomized block group design. Students were randomly assigned to experimental or control groups using the Research Randomizer (Urbaniak & Plous, 1997) where blocks of three were filled as students completed eligibility criteria. The independent variable for this study was critical thinking programs. The dependent variables were post-test scores on the California Critical Thinking Skills Test-2000 and the students' academic achievement as determined by their final grade. Pre-test data on the California Critical Thinking Skills Test-2000 was used as the covariate. Figure 10 illustrates the design for this study where graduate assistants (GA1, GA2) provide direct instruction in the Thinker's Guides (GA1) and Rationale (GA2).

Pre- Critical Thinking	Sex		Post- Critical Thinking	Follow-up Critical Thinking
CCTST- 2000	Male	Female	CCTST- 2000	CCTST-2000 Total, subscales Final Grade
GA1	12	14		
GA2	7	17		
Control	14	14		

Figure 10. Research Design Diagram for Critical Thinking Project.

Population

The subjects for this study were 78 undergraduate Freshman students attending a rural southeastern state university in Pennsylvania who were subject to being dropped from courses they were repeating and potentially from the

department of their major due to the university's 3-Repeat Rule. Students who repeat courses are identified by the Office of the Registrar each semester. Students identified by the Registrar's Office who were repeating courses two or more times during the spring 2007 semester were referred by the Registrar to the Office of Academic Advisement to meet with their advisors (Appendix A). The letter also referenced the university's policy regarding course repetitions (Appendix B). Students were also referred to the Office of Learning Services to determine if academic interventions, disability screening, or additional services such as tutoring were available to assist them.

Sample

Characteristics of the Sample

Male and female students from various ethnic backgrounds and majors participated in this study. The population at the university as of Fall 2007 was composed of 7,259 undergraduate and 1,047 graduate students. Forty-two percent of the participants were male (n=33) and 58% (n=45) were females. Based on demographic information collected from the participants, there were differences in the ethnicity of the study sample when compared to the general university student body. In the sample, 54% (n=42) were African-American, 32% (n=25) were Hispanic, 12% (n=9) were Caucasian, and 2% (n=2) were Mixed/Other (university student body: 78% Caucasian, 6.6% African-American, 3.3% Hispanic, and 9.9% other). These differences may be due to programs on campus that work with special admit students who are admitted with low SAT scores and may be in need of additional assistance for academic progress.

Special admission programs at this university are designed for students who have low combined SAT scores (750 to 1000), developmental issues related to academics, and low income students whose educational opportunities may have been limited. Students in these programs can be described as 62% African-American, 31% Latino and Asian, and 6% Caucasian. All of these students failed courses in their first semester at the university. This failure may have been a result of the adjustment students experience during their transition from high school to college that prompted them to seek assistance early in their educational careers. There were also regular admission students who participated in the study who continued to fail despite adequate SAT scores, regular admission, and educational opportunities. In addition, flyers were available throughout campus and it is possible that advisors of these students suggested this research study as an additional resource to assist them (Appendix C).

Additional characteristics of the subjects for this study were the number of major and non-major course repeats students reported, age, tutoring and study habits, prior knowledge of critical thinking, high school preparation for college, and whether they were taught how to think critically. Forty-one percent of the students in this study were repeating courses in their major, while 64% of students were repeating general education courses. Ninety-six percent of the subjects in this study were freshmen in the 17-19 age range. The university population is composed of 35% freshmen.

Tutoring is a service that is offered at no charge to any student at this university who makes a request. Demographic information revealed that 74% who were repeating courses did not seek tutoring in the course they were repeating. This was surprising since 91% of students in this sample reported they had met with their advisor each semester. While students did not seek tutoring for courses they were repeating, 35% reported studying two or more hours for the course they were repeating.

Students were surveyed regarding their prior knowledge of critical thinking. Students were asked to choose 1) None for no prior knowledge of critical thinking, 2) Limited for exposure to critical thinking based on teacher introduction of the concept without formal instruction or practice, 3) Average for teacher introduction, formal instruction, and practice demonstrating critical thinking in at least one class for the duration of that class, 4) Above-Average for teacher introduction, formal instruction, and practice demonstrating critical thinking in two or more classes for the duration of those classes, and 5) Advanced for teacher introduction, formal instruction, specific course in critical thinking, and the completion of a project or paper demonstrating expertise in critical thinking. Four percent of the students in this study reported no prior knowledge or instruction in critical thinking, 13% reported limited knowledge, 49% reported average knowledge, 29% reported above-average knowledge, and 5% reported advanced knowledge.

Students were surveyed regarding their high school preparation for college and whether they were sufficiently taught critical thinking while in high

school. Fifty-three percent of the students reported sufficient high school preparation for college and 72% reported being taught critical thinking skills while in high school. Table 1 illustrates the complete list of demographic characteristics of the research participants for this study.

Method of Subject Selection

Notification of this research study was provided by the Registrar to 906 students in the spring 2007 semester because they were in immediate danger of being dropped from the courses they were repeating. Students were also notified because the number of times a student repeats a course puts the student at risk for being dropped from the course and the department of their major. Students repeating a course one or more times were notified. Registrar notification to students who are repeating courses each semester is a proactive measure and a university retention initiative that also encourages students to take a realistic look at their majors to determine if a change in major should occur. It also serves as an opportunity for students to get additional help prior to being dismissed from courses and/or from academic departments.

Following the mailing of the 3-Repeat Rule letter, the Registrar sent an additional 906 notices about this study to the same students who received the first letter. Notices were sent one month apart. The notice about the study was sent on behalf of the Tutoring Center and students were invited to contact the Tutoring Center directly if they were interested in participating in this study. There was no connection between the 3-Repeat Rule letter students received from the Registrar and any expectation for students to participate in the study because the

Tutoring Center was identified in the correspondence rather than the Office of the Registrar. Advertisements about the study were also placed strategically around campus in high volume student areas and buildings that included the computer, student and tutoring centers. Finally, the study was advertised on the university tutoring center website to solicit student participation.

Ninety-six students from the first notification sent by the Registrar consented to participate in this study. The second notice that was sent to students by the Registrar resulted in an additional 47 participants. A total of 143 students consented to participate in this research study. There were eligibility criteria to participate in this study. Initial eligibility criteria for students to participate in this study was a Category Test: Computer Version Research Edition (CAT:CV) Error Score of 26 or more errors. Fourteen students were screened and found ineligible based on their error scores of less than 26 on the CAT:CV. A group of 15 students from the initial total requested to participate in a group held on Saturdays due to school, work and other obligations. However, following screening and pre-testing, these students elected to discontinue for the same reasons.

Participation in all facets of this study was required. Students who were unable to participate fully were removed from this study. Four students consented to participate, but did not come in for screening or testing and were removed from this study. There were three students who completed all pre-intervention requirements, but did not follow-through with interventions and were removed from this study. There were four students who discontinued their

participation following the first few sessions, citing upcoming graduation, class projects, work schedules, and personal issues as their reasons for discontinuing.

Table 1

Demographic Characteristics of the Study Participants

	<u>Thinkers' Guides</u>		<u>Rationale</u>		<u>Control</u>		<u>Total</u>	
	n=26	%	n=24	%	n=28	%	n=78	%
Sex								
Male	12	46	7	29	14	50	33	42
Female	14	54	17	71	14	50	45	58
Age								
17-19	25	96	24	100	27	96	76	98
Over 30	1	4	0	0	1	4	2	2
Ethnicity								
African - Amer.	12	46	17	71	13	46	42	54
Caucasian	4	15	1	4	4	14	9	12
Hispanic	9	35	6	25	10	36	25	32
Mixed/Other	1	4	0	0	1	4	2	2
Year								
Freshmen	26	33	24	31	28	36	78	100
School								
Humanities	7	27	9	38	5	18	21	27
Science	9	35	8	33	5	18	22	28
Social Sciences	6	23	1	4	9	32	16	21
Math	3	12	4	17	4	14	11	14
Education	1	3	2	8	4	14	7	9
Undecided	0	0	0	0	1	4	1	1
Number of students who repeated courses in their major								
Yes	11	48	7	29	14	50	32	42
No	15	52	17	71	14	50	46	58

Table 1 (Continued)

Demographic Characteristics of the Study Participants

	<u>Thinkers' Guides</u>		<u>Rationale</u>		<u>Control</u>		<u>Total</u>	
	n=26	%	n=24	%	n=28	%	n=78	%
Number of students who repeated general education courses								
Yes	15	58	20	83	15	54	50	64
No	11	42	4	17	13	46	28	36
Number of times students repeated courses in their major								
0	15	58	8	33	5	18	35	45
1	10	38	16	67	23	82	38	49
2	1	4	0	0	0	0	3	4
3	0	0	0	0	0	0	1	1
4	0	0	0	0	0	0	1	1
Number of times students repeated general education courses								
0	11	42	3	13	13	46	27	35
1	15	58	21	87	15	54	51	65
Meet with advisor								
Yes	23	88	23	96	25	89	71	91
No	3	12	1	4	3	11	7	9
Tutored in repeat course								
Yes	7	27	8	33	5	18	20	26
No	19	73	16	67	23	82	58	74
Hours of tutoring								
N/A	18	69	15	63	21	75	54	69
1	5	19	2	8	3	11	10	13
2	2	8	5	21	3	11	10	13
3	1	4	1	4	1	3	3	4
>3	0	0	1	4	0	0	1	1
Declared or undeclared								
Undeclared	5	18	0	0	1	6	6	8
Declared	21	82	24	100	27	94	72	92

Table 1 (Continued)

Demographic Characteristics of the Study Participants

	<u>Thinkers' Guides</u>		<u>Rationale</u>		<u>Control</u>		<u>Total</u>	
	n=26	%	n=24	%	n=28	%	n=78	%
Changed major due to an inability to meet department requirements								
Yes	1	4	1	4	0	0	2	3
No	25	96	23	96	28	100	76	97
Changed major due to repeat courses								
Yes	0	0	1	4	0	0	1	1
No	26	100	23	96	28	100	77	99
Financial hardship								
Yes	0	0	0	0	1	1	1	1
No	26	100	24	100	77	99	77	99
Graduation delay								
Yes	0	0	0	0	1	4	1	1
No	26	100	24	100	27	96	77	99
Sought professors assistance								
Yes	22	77	23	96	27	96	72	92
No	4	13	1	4	1	4	6	8
Knowledge of critical thinking								
None	2	8	0	0	1	4	3	4
Limited	3	12	4	17	3	11	10	13
Average	13	50	11	46	14	50	38	49
Above-Average	8	30	8	33	7	25	23	29
Advanced	0	0	1	4	3	10	4	5
Number of students who report they were taught critical thinking								
Yes	18	69	16	67	22	92	56	72
No	8	31	8	33	6	8	22	38

Table 1 (Continued)

Demographic Characteristics of the Study Participants

	<u>Thinkers' Guides</u>		<u>Rationale</u>		<u>Control</u>		<u>Total</u>	
	n=26	%	n=24	%	n=28	%	n=78	%
Number of hours subjects study each week in general								
1	15	58	16	67	13	46	44	56
2	8	30	6	25	8	29	22	28
3	0	0	2	8	5	18	7	9
>3	3	12	0	0	2	7	5	7
Number of hours of subjects study each week for repeat course								
0	0	0	0	0	0	0	0	0
1	20	77	16	67	15	53	51	65
2	3	12	6	25	7	25	16	20
3	1	4	1	4	3	11	5	7
>3	2	7	1	4	3	11	6	8
Registration status								
Full-time	25	96	22	92	26	93	73	94
Part-time	1	4	2	8	2	7	5	6
Employment status								
Not Employed	15	58	16	67	18	64	49	63
Full-time	0	0	0	0	1	4	1	1
Part-time	11	42	8	33	9	32	28	36
Hours worked weekly								
0	4	15	17	71	18	64	39	50
<10	20	77	5	21	8	28	33	42
10-15	2	8	0	0	0	0	2	3
16-20	0	0	0	0	1	4	1	1
21-25	0	0	1	4	0	0	1	1
26 or more	0	0	1	4	1	4	2	3

Table 1 (Continued)

Demographic Characteristics of the Study Participants

	<u>Thinkers' Guides</u>		<u>Rationale</u>		<u>Control</u>		<u>Total</u>	
	n=26	%	n=24	%	n=28	%	n=78	%
Number of students who repeated courses despite tutoring								
Yes	2	8	1	4	2	7	5	6
No	24	92	23	96	26	93	73	94
Sufficient high school preparation in critical thinking								
Yes	23	88	7	29	11	39	41	53
No	3	12	17	71	17	61	37	47

Finally, five students who attended all sessions but declined to be post-tested due to class projects, work schedules, and personal issues were removed from this study.

A total of ninety-eight students actually completed this study in its entirety. All students were required to attend tutoring as a condition of participating in this study. Participants were entitled to 3 hours of tutoring each week in the repeated course for the duration of this study. A condition for participation in this study was that students attend at least one hour of tutoring each week throughout this study. A total of 51 students (52%) attended tutoring one hour each week, 40 students (41%) attended tutoring two hours each week, and 7 students (7%) attended tutoring three hours each week.

Students who identified themselves as interested in this study and who repeated any course at least once were permitted to volunteer for this study.

Students who were not chosen for the study or those interested in trying a different method of intervention other than the one assigned to them for this study were offered follow-up participation through the Tutoring Center. No student requested a change in the group in which they were assigned. Several students discontinued the study. Their discontinuation may have been related to the method of their group assignment or the instruction provided by their graduate assistant. Finally, students who were assigned to the Control Group may not have been able to maintain a commitment to working independently on the materials that were available to them.

Sample Size

None of the current or past research in critical thinking suggested a specific sample size for studying the critical thinking of post-secondary students. Researchers conducting studies in critical thinking in university courses have used one or more sections using the students in those sections that ranged from 25 to 30 students in each section. Other research studies used smaller specialty groups composed of nursing, pharmacy, and engineering students to evaluate critical thinking among one or more groups. Samples sizes from previous research have ranged from 51 to 139. Table 2 summarizes that research.

The next method for considering sample size for this study was based on research by Cohen (1992) who suggested that statistical inference is based on four variables: sample size, significance criterion, population effect size, and statistical power where each is a function of the other three. Cohen (1992) suggests the best method for determining sample size may be to set the level of

power, to determine the long term probability of rejecting the null hypothesis (H_0), significance, and effect size. According to Cohen (1992) to lessen the probability of committing a Type II error or failing to reject a false null hypothesis, a power of .80 (1-Beta or .20) and alpha of .05, is suggested and appropriate for general use. With $\alpha = .05$ and a power of .80, the Beta alpha ($\beta\alpha$) ratio becomes .20 to .05 or 4:1 for the more serious risk of committing a Type I (false null rejection) than for a Type II error or false null acceptance (Cohen 1992).

According to Cohen (1992), power analysis cannot be done effectively without considering effect size or the degree to which the null hypothesis differs from an alternative hypothesis or different from zero. The discrepancy between the null and alternative hypothesis is the effect size.

The sample size for this study was calculated according to past research studies and considered the degree of difference desired on the CCTST-2000 Post-test Total Ranked Score. Based on past studies, an average of the number of participants was 84. According to the CCTST manual (1990), the mean student performance on the CCTST pre-test is 15.89 and the average mean improvement on the CCTST as a post-test is 20% or a CCTST score of 19.1. Based on the difference desired with a power of .80 and alpha of $p < .05$, 157 subjects would have been required. The number of subjects (78) was far less than the desired number. Therefore, the likelihood of making a Type I Error was increased and any significance found may not truly exist.

Table 2

Critical Thinking Research Studies and Sample Sizes

Research Study & Description	Number of Groups	Sample Size
Phillips, C., Chestnut, R., & Rospond, R. (2004). The California critical thinking instruments for benchmarking, program assessment, and directing curricular change.	1	89
Reed, J. (1998). Effect of a model on student achievement in primary source document analysis, interpretation, and argumentative reasoning, critical thinking dispositions, and history content in a community college history course.	2	52
Hanley, G. (1995). Teaching critical thinking: Focusing on metacognitive skills and problem solving.	2	65
Zepure, S. (2006). The effect of concept mapping on critical thinking skills and dispositions of junior and senior baccalaureate nursing students. In <i>Concept Maps: Theory, Methodology, Technology</i> .	2	77
van Gelder, T. (2002) Reason: Improving informal reasoning.	2	51
Gadzella, B. (2002, Spring). Prediction of GPA with educational psychology grades and critical thinking scores.	3	114

Table 2 (Continued)

Critical Thinking Research Studies and Sample Sizes

Research Study & Description	Number of Groups	Sample Size
Harrell, M. (2005). Using argument diagrams to improve critical thinking skills in 80-100 What Philosophy Is.	4	139

Note. The average number of subjects in similar research studies was 84.

Assignment

Students were randomly assigned to experimental or control conditions following their completion of a voluntary consent and a screening using the CAT:CV. Students were assigned a number on a first-come, first-served basis that also corresponded to their position for the randomization process. For example, the first student who consented and completed the CAT:CV was assigned the number one and was placed in position one (p1). A student assigned the number 50 was placed in position 50 (p50), and so on until all numbers and positions were assigned. Using the “Research Randomizer” program, 48 trial blocks of 3 participants each were used until all 143 students were assigned a number of 1, 2 or 3 to represent treatment conditions. The following illustrates the random assignment of subjects to treatment conditions:

p1=3, p2=2, p3=1 or p74=1, p75=3, p66=2

This blocked design random assignment attempted to ensure the equality in sample sizes across treatment conditions and the researchers’ ability to

maintain statistical power. Following the random assignment of treatment conditions, participants were assigned to one of three groups for this study: Experimental Group One: The Thinkers' Guides Group; Experimental Group Two: the Rationale Group; or Group Three, which was the Control Group. Students in the Control Group worked independently on critical thinking in the Tutoring Center.

Measurement

Instruments

Category Test: Computer Version-Research Edition

The Halstead-Reitan Category Test is a well known component of the Halstead-Reitan Neuropsychological Test Battery. The Category Test is generally used to evaluate brain damage and is considered the most effective measure in the Halstead-Reitan Battery to detect brain damage. The Category Test also evaluates abstract reasoning, complex problem-solving, and experiential learning.

Research studies have used the Halstead-Reitan Category Test to gather information on individuals who demonstrate adequate visual-perceptual and language skills, but have poor abstract reasoning. According to Allen, Goldstein, and Mariano (1999), poor capacity for abstraction may be the reason individuals with adequate visual perceptual, special construction, and language skills do poorly on the Category Test.

Like the standard form of the Halstead-Reitan Category Test, the Category Test: Computer Version – Research Edition (CAT:CV) taps into

multiple domains of complex reasoning including the executive functioning area of the frontal lobe of the brain that governs one's ability to plan, execute, and monitor one's own behavior (Minassian, Perry, Carlson, Pelham, & DeFilippis, 2003). The results of the CAT:CV also provide insight into those students whose abstract reasoning and critical thinking skills are barriers to successful performance at the post-secondary level (Allen, Goldstein, & Mariano 1999). In a study comparing subject performance on the standard form of the Category Test and the computer form, results revealed factor equivalence between forms and evidence that both forms measure a similar spatial ability construct (Berger, Chibnall, & Gfeller, 1997).

The original Halstead Category Test is available in three age formats that include an adult format for ages 15 and older, an older children format for ages 9-14, and a children's format for ages 5-8. The Category Test is often used to detect brain damage, but it also evaluates abilities of higher-order thinking such as abstraction, reasoning, logical analysis, conceptualization, complex problem-solving, experiential learning, and the ability to draw specific conclusions from general information.

The number of errors subjects make on the Category Test is recorded and compared to cut-off scores to determine their level of impairment. Choca et. al (1997) referenced Heck and Bryer's (1986) study about the error scores on the Category Test suggesting that good scores reflect an intact brain, reasonable intellectual abilities, maturity in cognitive development, and the ability to think with concentration and efficiency. On the adult battery and based on Heaton

norms, error scores between 0 and 25 are considered very normal or a Halstead-Reitan score of 0. Error scores between 26 and 45 are considered normal as well and are given a Halstead-Reitan score of 1. However, even though the score is within the normal range, error scores between 26 and 45 represent performance that is not quite as good as might ideally be expected. Error scores between 46 and 64 are given a Halstead-Reitan score of 2 and suggest mild to moderate impairment. Error scores above 65 are considered severe and given a Halstead-Reitan score of 3 and suggestive of impairment in brain functioning when the Category Test is used to evaluate brain damage. Scores that were at or above 26 were used for this study.

The HCT in its original format is a series of 208 pictures of geometric figures divided into seven subtests and administered using a screen that is manually operated by the examiner. The HCT can take one to two hours to administer depending on the subject. Subjects are asked to make a decision about each picture and which number from 1, 2, 3, or 4 corresponds to a principle that runs throughout each subtest. Subjects press a lever that corresponds to the number of their choice and hear a bell for a correct answer or a buzzer for an incorrect answer. It is assumed that subjects will respond correctly to all items in a subtest once they figure out the principle that runs throughout the subtest.

The first six subtests have only one principle that runs throughout them. However, the last subtest has more than one principle throughout it because it is made up of items previously shown to subjects. This subtest is the most time-

consuming subtest for most subjects and typically takes longer to administer than the others. All subjects are given a trial to familiarize themselves with the keyboard and sounds related to correct and incorrect answers.

There are several forms of the Category Test that include the original slide projector, short form, and computerized (CAT:CV) versions. The CAT:CV consists of the same seven subtests as the original HCT. Like the original Category Test, the CAT:CV offers 208, 120, and 108 item versions. The CAT:CV takes about 30 minutes to administer and allows the examiner to choose the number of subtests. The examiner reads the exact directions that are provided on the original Category Test. Although subjects taking the original version of the Category Test used a projector and screen on which they pressed levers for the correct response, subjects taking the computer version use pre-labeled keys to enter responses.

On the CAT:CV, subjects are also asked to use keys on the keyboard that are pre-labeled 1, 2, 3, and 4 and expected to identify the principle that runs throughout each subtest. Subjects are taken through a trial to familiarize them with the keys and sounds related to correct and incorrect answers. As in the original Category Test, the computer version also uses a bell and buzzer for correct and incorrect answers respectively. Error scores are calculated and cut-off scores for normality equal those of the original Category Test. The CAT:CV provides a report generated by the program that identifies the exact errors by items on each subtest, T-score, and response time per item.

The computerized version of the Category Test (CAT:CV) was developed by Nick DeFilippis and the staff at the Psychological Assessment Resources, Inc. to assist in the administration and scoring of the Category Test. This is achieved through the use of test indicators that are not generally scored such as response latency per subtest and total test, elapsed time per subtest and total test, and average response latencies for correct and incorrect responses (DeFilippis, 2002).

According to DeFilippis (2002), studies investigating the robustness of the Category Test under different administration procedures have shown the Category Test to be unaffected by the apparatus used in its administration, which may be due to the relatively pure cognitive processing involved when solving test items. Strauss, Sherman, & Spreen (2006) also report the Category Test as a robust instrument that can withstand variations in administration such as the book or computer format. The computer format offers several advantages over the standard administrations, such as error-free administration and the ability to collect additional data beyond the number of errors.

There are several psychometric properties of note on the Category Test. Item analysis of the original Category Test revealed that subtests one and two were too easy for subjects, even if their use was to familiarize test takers with the test (Choca, et. al 1997). There were several norms collected on the original 208 item version of the Category Test. Halstead (1947) and Heaton (1991) norms are referred to most often regarding test results (Choca, et. al, 1997). According to Choca, et. al (1997), researchers have concluded that age is a primary factor that

contributes to individual error score differences between examinees on the Category Test accounting for a .54 correlation coefficient.

Education is another factor known to predict the total error score on the Category Test. There is an interaction effect between age and education on the Category Test as well. According to Choca, et. al (1997), less educated individuals up to the age of 60 show greater age-related impairments than their same-aged peers. Beyond age 60, both groups tend to perform equally on the Category Test. Gender has not shown to be a significant factor among the American population (Choca, et. al, 1997). The adult version of the Category Test is meant for individuals aged 15 years, 6 months and older although adequate norms developed by Heaton are only available for ages 20-85. The Heaton norms are the preferred norms because they provide different ethnic, age, and gender information for subjects (Choca, et. al, 1997).

Choca et. al (1997) reported on the reliability of the Category Test based on test-retest studies by Matarazzo that revealed low ($r = .60$) test-retest reliability on normal individuals. According to Choca et. al (1997), this may be due to test takers having benefited from having the same test before. Russell (1992) reported that the low reliability on the Category Test may be partly due to the restricted range of scores used, but when the score range is expanded the correlation coefficient improves to $r = .88$. According to Kilpatrick (1970) and Moses (1985), the Category Test repeatedly shows a split-half reliability of .90 or above.

Numerous researchers have reported on the validity of the HCT. According to Strauss, et. al (2006), the Halstead Category Test shows moderate correlations with Full Scale IQ's of the Wechsler intelligence scales, particularly with the Performance IQ. The Category Test shows a moderate to high correlation with the Matrix Reasoning and Letter-Number Sequencing subtests of the WAIS-III. Factor-analytic findings suggest that the Category Test loads on several factors depending on the subtests. Subtests III, IV, and VII load on spatial reasoning and are affected by the age of the subject. Subtests V, VI, and sometimes VII load on proportional reasoning and performance on these subtests is affected by the age of the subject and head injury. The computer version jumps to the next subtest when it has enough information to predict a subject's performance on a given subtest.

Research studies on the convergent validity of the Category Test with other Halstead measures, Wechsler IQ's, and the Wisconsin Card Sorting Test reveal that it shows only modest correlations (Choca et. al 1997). According to Choca, et. al (1997), gifted individuals demonstrate a range of problem solving skills whereas those with low abilities generally demonstrate poor problem solving. Studies of clinical validity reveal that subjects with brain dysfunction perform poorly on the Category Test (Choca et. al, 1997).

Demographic Survey

A demographic survey to collect descriptive data about the subjects in this study was the fourth instrument used in this study. Developed by this researcher, the survey was composed of 27 questions regarding characteristics of the

sample population. Basic descriptive statistics were used to summarize students' demographic information from the demographic survey such as sex, age, class level, and school.

California Critical Thinking Skills Test

The California Critical Thinking Skills Test (CCTST) Form 2000 was given as a pre-test of subjects and the fifth instrument used in this study. The CCTST is available in three forms: Form A, Form B, and Form 2000. The CCTST – 2000 was the only instrument used for post-testing and the sixth instrument used in this study. The CCTST-2000 is a standardized 34-item multiple choice test developed by Dr. Peter Facione and is based on the American Philosophical Association's Delphi Panel's consensus of the conceptualization of critical thinking known as the Delphi Report of 1990. Items on the CCTST were derived based on the consensus of 46 experts on the Delphi Panel.

The CCTST-2000 is designed for use with undergraduate students and adults. The CCTST-2000 identifies the strengths and weaknesses of one's skill in making reflective, reasoned judgments when deciding what to believe or what to do (Insight Assessment, 2007). The CCTST-2000 also targets the core critical thinking skills that are considered essential for college. The CCTST-2000 takes 45 minutes to complete under timed conditions and can also be administered untimed.

According to the CCTST-2000 manual (Insight Assessment, 2002), the items vary in several ways. Items require subjects to engage in analysis of the meaning of sentences, complex integration of critical thinking skills, correct

inferences based on assumptions, evaluation of inferences and objections to assumptions. The CCTST-2000 requires subjects to apply reasoning that is consistent with a skilled critical thinker. The CCTST-2000 can be taken in the booklet using a paper/pencil format with a scantron sheet or through an online format set up by Insight Assessment that is the publisher of the test.

There are five subscales of critical thinking that are evaluated using the CCTST-2000 that are identified as Analysis, Evaluation, Inference, Deductive, and Inductive reasoning, as well as a total score of critical thinking. According to the CCTST-2000 Test Manual, the Analysis subscale assesses one's ability to comprehend and express a variety of experience, situations, date, etc. Analysis is used to identify the intended and actual inferential relationships among statements, concepts, etc. that are used to express beliefs, reasons, opinions and judgments and analyzes them into their component elements (Facione, Facione, Blohm, and Giancarlo, 2002). The Evaluation subscale requires the test taker to assess the credibility of statements that are based on human perception and to assess the logical strength of the inferential relationships among forms of representation such as descriptions, questions, etc.; requiring one to also state and justify one's reasoning (Facione, Facione, Blohm, and Giancarlo, 2002). The Inference subscale on the CCTST-2000 requires one to consider data, facts, judgments, beliefs, and evidence and considers these elements in the process of drawing conclusions (Facione, Facione, Blohm, & Giancarlo, 2002). The Deductive Reasoning subscale requires one to evaluate information for truth. According to Facione (Facione, Facione, Blohm, & Giancarlo, 2002), it is not

possible to have valid deductive reasoning if all of the premises are true, but the conclusions are false. Conversely, the Inductive Reasoning subscale measures one's reasoning that the information at hand suggests a given conclusion is true, even if later it proves to be false (Insight Assessment, 2007). The Total Score on the CCTST-2000 is an assessment of one's overall reasoning or critical thinking ability that is derived from the Analysis, Evaluation, and Inference subscales that are considered core critical thinking skills (Insight Assessment, 2007).

Completed CCTST-2000 protocols were scored using the Capscore system from Insight Assessment. Reports were generated that included descriptive statistics for the group as a whole as well as sub-scale statistics. The CCTST-2000 is normed for both two-year and four-year college students. Form 2000 was used for both pre-testing and post-testing and through repeated testing by Insight Assessment; no test effect has been shown. Form 2000 is reportedly a more robust form and is superior to Form A that was developed in 1992 (Facione, Facione, Blohm, & Giancarlo, 2002). The correlation between scores from the items on Form 2000 of the CCTST and Form A of the CCTST was 0.912 for sample one and 0.871 for Sample Two (Facione, Facione, Blohm, & Giancarlo, 2002).

The validity of Form A of the CCTST has been well established and the integral relationship between the two instruments provides strong evidence for the validity of Form 2000 of the CCTST (Facione, Facione, Blohm, & Giancarlo, 2002). The validity of the CCTST-2000 is addressed by examining it in terms of content validity, construct validity, and criterion validity. Content validity refers to

how well the test items represent items specific to critical thinking. Items included in the CCTST-2000 were chosen based on its theoretical relationship to the Delphi Panel's conceptualization of critical thinking (Facione, et. al, 2002). Construct validity refers to the extent to which the test measures the Delphi experts consensus of critical thinking. Finally, criterion validity refers to the ability of the CCTST-2000 to predict some external criteria such as academic success (Facione, et al., 2002). The CCTST-2000 is reported to have a content validity of .74 and moderate criterion validity with grade point average and SAT math and verbal scores.

Construct validity for the CCTST-2000 is high as indicated by a 95% consensus of the Delphi panel experts on the components of critical thinking (Facione, et al., 1992, 2002, 2004). Test reliability for the CCTST-2000, based on the Kuder-Richardson 20 ranges from .68 to .70 even though .80 or above is generally expected for a single concept. However, the CCTST-2000 is a multiple construct instrument measuring five sub-areas (analysis, inference, evaluation, induction, and deduction). Therefore, a Kuder-Richardson 20 score of .68 – .70 is acceptable (Facione, et al., 2002).

Procedures

Students who repeat courses multiple times often come to the Office of Learning Services for additional services such as screening to determine if an undiagnosed learning disability exists. The CAT:CV is routinely given to students as a part of the learning disability screening. Each student who demonstrated interest in participating in this study was given an informed consent for the study

and an informed consent for the initial screening using the CAT:CV. Following the signed consent forms, students were screened using the CAT:CV.

The researcher for this study was the Director of the Office of Learning Services and is a Pennsylvania Certified School Psychologist who completed doctoral level training in neuropsychological assessment that included the Halstead-Reitan Category Test – original box form and the CAT:CV. The researcher has also developed workshops in critical thinking based on current research in critical thinking. Graduate Assistants assigned to the Office of Learning Services and the Tutoring Center, who are also clinical and school psychologists in training, were trained by this researcher to administer all assessment instruments in this study. Each of the graduate assistants has completed courses in testing and measurement. Although the Graduate Assistants were trained to administer the tests and programs, they were not briefed about the study or its intended purpose. Table 3 illustrates the task table for this study. Table 4 outlines research questions, analysis, et.

Following the initial screening using the CAT:CV, students were considered eligible for this study based on their number of errors. Any student who produced 26 or more errors on the CAT:CV was offered the opportunity to participate in this study. Each student who was eligible for this study and agreed to participate was given the CCTST-2000 as a pre-test.

Participants from all three groups were tutored throughout this study in the course they were repeating. Subjects in Experimental Group One received the Thinker's Guides program and tutoring. Subjects in Experimental Group Two

received the Rationale program and tutoring. Subjects in the Control group received tutoring and engaged in independent study in critical thinking. All students in Group One and Two met every Monday or Wednesday in the Tutoring Center and the Assistive Technology Lab from 3:30 pm to 5:00 pm. The additional 30 minutes each session was to explain tasks and conduct on-site activities.

Treatment Methods

Thinker's Guides

Participants were randomly assigned to Experimental Group One (Thinkers Guide/Tutoring), Experimental Group 2 (Rationale/Tutoring), or the Control Group (Tutoring/Independent study group). Experimental Group One received direct instruction in the Thinker's Guides to improve critical thinking.

Students studied an assigned guide each week and were provided guided instruction and review of each guide using power point presentations. Students were given activities during each session to provide an opportunity for them to apply the skills learned during the session. Activities and examples present in the guides were used to facilitate group discussions and to ensure understanding of concepts presented in the guides. Several of the guides contain information that is repetitious in order to provide additional opportunities for students to master the content. Specifically, the guides reviewed Paul's model of critical thinking and demonstrated explicitly how the model can be applied to various reasoning tasks (Paul & Elder, 2006).

As a reminder, Paul's model has three main components: elements of thought/reasoning, universal intellectual standards, and intellectual traits. Paul's definition of critical thinking is as follows:

Critical thinking is that mode of thinking – about any subject, content or problem – in which the thinker improves the quality of his or her thinking by skillfully taking charge of the structures inherent in thinking and imposing intellectual standards upon them (Paul, Fisher and Nosich, 1993).

Fourteen of the guides chosen for this study were those related to improving critical thinking for students at the post-secondary level. The first guide used was "Critical Thinking Competency Standards" (CTCS), a guide used by this researcher and graduate assistants to gain an understanding of the evaluation of students' critical thinking and at what levels students should achieve competency. CTCS provides a continuum of student expectations, can be contextualized for any academic discipline, and can identify how students are using critical thinking as a primary tool for learning (Paul and Elder, 2005). A complete list of the Thinker's Guides used for participants in this study is as follows:

Table 3

Direct Instruction in Critical Thinking Skills Study Task Table

<u>#</u>	<u>Name</u>	<u>Description</u>	<u>Begin</u>	<u>End</u>	<u>Person</u>
1	Research Idea	Design a research study to evaluate the effect of direct instruction in critical thinking on the improvement of critical thinking and academic achievement	08-2005	06-2006	Researcher
2	Refine Study	Review assessment tools of critical thinking skills. Review programs to improve critical thinking skills	07-2006	11-2006	Researcher
3	Obtain Tools and Materials	Obtain assessment tools and intervention methods to be used in this study	12-2006	01-2007	Researcher
4	Pre-assessment	Screen all potential subjects with the Halstead-Reitan Computer Category Test – Research Edition, Pre-test using the California Critical Thinking Skills Test (CCTST) Obtain demographic surveys from subjects	01-2007	02-2007	Graduate Assistants
5	Treatment	Experimental Group 1 uses the Thinkers' Guides, Experimental Group 2 uses Rationale, and the Control Group engages in independent study in critical thinking. All groups engage in tutoring in a course they are repeating.	02-2007	06-2007	Graduate Assistants Tutors
6	Post-assessment	Post-test all subjects using the California Critical Thinking Skills Test. Send pre- and post tests of the California Thinking Skills Test to Insight Assessment for scoring Obtain final grades in repeated courses of subjects	06-2007	06-2007	Graduate Assistants

Table 3 (Continued)

Direct Instruction in Critical Thinking Skills Study Task Table

<u>#</u>	<u>Name</u>	<u>Description</u>	<u>Begin</u>	<u>End</u>	<u>Person</u>
7	Data Entry	Obtain California Critical Thinking Skills Test scores from Insight Assessment and enter in SPSS data file Data entry from demographic survey	07-2007	08-2007	Researcher
8	Interim Report Preparation	Check data and examine data to see if it meets the assumptions for analysis to be used. Run data analysis. Interpret results. Write report.	09-2007	10-2007	Researcher
9	Interim Defense	Meet with committee to review Chapters 1-3. Obtain suggestions for revisions. Examine data to see if it meets the assumptions for analysis. Re-run data analysis. Interpret results. Write the report.	11-2007	01-2008	Researcher
10	Final Report Review	Meet with the committee to review and refine report.	02-2008	03-2008	Committee Researcher
11	Research Defense	Present defense to committee members	04-2008	04-2008	Committee Researcher

Critical Thinking Concepts and Tools	The Human Mind
How to Study & Learn a Discipline	Critical & Creative Thinking
The Art of Asking Essential Questions	Active & Cooperative Learning
Analytic Thinking	Scientific Thinking
How to Improve Student Learning	How to Read a Paragraph
How to Write a Paragraph	Ethical Reasoning
Fallacies: The Art of Mental Trickery & Manipulation	

Handouts for the Thinker's Guides were provided to students in the experimental groups throughout the duration of this study. Figure 11 is an example of a handout provided to students for the guide "How to Improve Student Learning" (HISL). The handout was provided to students as a summary of the guide for HISL because it is a guide specifically designed for instructors and issues related to students. The purpose of this handout was to serve as a reminder to students what instructors use to evaluate their learning on an ongoing basis. This researcher thought it would be helpful for students to have a reminder of this throughout this study since they were still in classes.

This researcher considered an alternative instructional method to improve the critical thinking and reasoning skills of post-secondary students. Learning to Learn is a program designed by Marcia Heinman (Heinman & Slomianko, 2004) that is used in a course format. Learning to Learn has been endorsed by the United States Department of Education as a program that has shown significant results in improving the critical thinking skills of post-secondary students (Heinman & Slomianko, 2004). However, after consulting with the author of Learning to Learn, this researcher elected to conduct a

- Goals of this Session
- To provide you with some practical ideas to:
 - Help you understand your class structure
 - Assess & improve academic abilities
 - Get the most out of class time
- The First Day of Class
- Often thought of as the easiest day
 - Most students don't pay much attention because "it won't be on the test".
 - However you receive one of the most important pieces of paper that day...
- The Syllabus
- Like a contract for your class.
 - A good one includes:
 - Key concepts for the course: Look at this like an introductory chapter to a text book. This section includes the overarching ideas that will be presented in the course. It can provide some background information or themes that the professor thinks are important. This section also lets you know what thinking will be involved in the course (example: historical, biological, psychological thinking)
 - Course goals: Course goals provide you with an idea of what you should get out of the course (learning certain theorists, being able to conduct a certain experiment, learning counseling interventions).
 - Course plan: How the class will be taught (lecture, discussion based, class participation). There should also be a semester plan with weekly reading or the due dates for assignments or test dates.
 - Requirements: what the student is responsible for; attendance, participation, readings, assignments, presentations etc.
 - Grading/grading policies: a break down of how much assignments are weighted in the class, what constitutes "A" "B" "C" "D" "F" work, and any honor codes concerning plagiarism.
 - Instructor information: office hours, phone, e-mail
 - Additional information: example for assignments, additional resources besides textbooks etc.
 - The syllabus is like a contract between you and your professor, if you read it and understand it, there should be no surprises during the semester.
- How to Come to Class
- The student mindset should include the following:
 - Seeing class time as practice: Class time is a time to learn, not just sit and take notes. You have to practice the concepts you are learning by participating, asking questions, listening to your peers, helping peers that are struggling. You should come to class prepared (having assignments and reading completed) and ready to do some work.

Figure 11. How to Improve Student Learning Adapted from *How to Improve Student Learning* by Dr. Richard Paul and Dr. Linda Elder.

- Being ready to think within your system: if you are in a math class, are you thinking like a mathematician? Owning the class and thinking like a professional in the field does makes the content more personal and opens up your mind to ask questions about how you fit the information into the field.
- Looking to make connections between what you learn and your personal life: Don't walk out of a classroom and not think about the material until you meet again for the next class, try to relate ideas to your everyday life. If you can make these connections, you will be more likely to learn and remember the information.

Assessing Your Skills:

How to tell if you are thinking critically in your classroom

Assessing Your Reading

- Understanding the P.O.V. of the author: It's important to understand that information presented in any text or author is coming from the point of view of the author which can be biased (good or bad) by the author's views within the field. Knowing certain questions to ask can help you understand where the author is coming from and how to look at the text as it relates to the field as a whole.
 - Questions to ask:
 - Is the writer's purpose clear?
 - Does the writer cite relevant evidence, experiences, and/or information essential to the issue?
 - Does the writer clarify key concepts when necessary?
 - Does the writer show a sensitivity to what he or she is assuming or taking for granted?
 - Does the writer develop a definite line of reasoning, explaining how well he or she is arriving at his or her conclusion?
 - Does the writer show sensitivity to alternative points of view or lines of reasoning? Does he or she consider and respond to objections framed from other points of view?
 - Does the writer show sensitivity to the implications and consequences of the position he or she has taken?
- Your own personal understanding of the text: One of the best ways to tell if you understand your reading is to ask yourself questions and put your answers in your own words.
 - Questions to ask
 - What is the purpose of the chapter?
 - What are the key terms or issues?
 - What information did the authors use in coming to these conclusions? How can I check if this information is accurate?
 - What conclusions can I draw from the chapter?
 - Does the author take any information for granted?
 - Could I explain the ideas of this chapter to a classmate?

Figure 11 (Continued). How to Improve Student Learning Adapted from *How to Improve Student Learning* by Dr. Richard Paul and Dr. Linda Elder.

- You can also make these questions more focused to deal with specific terms or ideas within the chapter.

Assessing Your Writing

- Building upon reading: putting it in your own words.
 - Answer study questions- your own or from the book: this can be valuable practice if exams are in the form of short answer/essay or if there are papers that are required for the course.
- Work together: it's helpful to read the work of your peers to see where you stand in relation.
 - Peer review
 - Work in groups and have one person read their paper (or answer to a study question aloud). Then take suggestions for improvement from the other members on content, clarity, relevance to topic. The advantage is being able to hear a question answered from different view points and learning how to strengthen your writing before it is graded by a professor.

Assessing Your Speaking

- Again we are building upon our reading and writing skills: having good speaking skills will help you when it comes time for class participation or class presentations. You have already seen some ideas of the need for speaking skills in the peer review section of the writing skills.
- Group activities
 - Teaching: The best way to gauge your understanding of a topic is to try and teach it to someone else. Have them ask you questions, and rate you on your clarity and content.
 - Group discussions: much like the peer review get together in a group and discuss study questions.

Conclusion

- The first day of class sets the tone
 - Know the class by knowing the syllabus
- Be in the right mind frame
 - Come to class prepared
 - Think within your discipline
- Assess yourself throughout the course
 - Reading
 - Writing
 - Speaking
 - Listening

Figure 11 (Continued). How to Improve Student Learning Adapted from *How to Improve Student Learning* by Dr. Richard Paul and Dr. Linda Elder.

study that did not require setting up the study as a credit course, which the author felt was the best format for obtaining subjects and the desired results.

Rationale

The Rationale Argument Mapping Program (Austhink, 2007) was the second treatment method used in this study and the treatment intervention for Experimental Group Two. Rationale is a computerized argument visualization program that uses argument mapping to help students build critical thinking and reasoning skills. Activities chosen to familiarize students with Rationale included a short group activity followed by an activity to create a reasoning map of “I should skip class today” as their main position.

Students were expected to use the evaluation tools to evaluate their arguments. Subsequent activities included using the Rationale program to demonstrate reasoning for the use of hydrogen fuel cells. Activities progressed to more extensive articles on acupuncture, allergy relief and an article on global warming. Figure 12 illustrates an activity for students for the session on scientific thinking. The activity is based on an article about global weather changes. All activities can be viewed in Appendix H.

The Control Group for this study engaged in independent study in critical thinking. Materials available for the Control Group included the thirteen Thinker's Guides (Paul & Elder, 2004, 2005, & 2006), Thinker's Guides review summaries (created by graduate students for availability on computer), activities, and the Rationale program on computer.

Following an introduction by the graduate assistants on materials and their use, the graduate assistant remained available only to answer technical questions. No direct instruction was provided. Following a thirteen-week intervention, students took a post- test using the CCTST- 2000.

- 1) Identify the main scientific **purpose** of the article:
- 2) State the **key scientific question** that the author is addressing:
- 3) What is the most important **information** in this article?
- 4) The main **scientific concepts** in this article are:
- 5) State the main **assumptions** that the author is making:
- 6) What are the **scientific inferences** of the reasoning in this article:
- 7) Identify the main **points of view** of this article:
- 8) Discuss the resulting **implications** from this article:

Figure 12. Scientific Thinking - Analyzing an Article.

Debriefing

Following the completion of this study, students were provided opportunities for debriefing in the Tutoring Center. Debriefing included information regarding the purpose for the study as well as the methods used.

Arrangements were made prior to the end of the semester for students who were unavailable for debriefing after the semester. The Tutoring Center offered written debriefing for students who requested this information. Debriefing occurred in groups led by the project director and/or graduate assistants. Graduate assistants and student participants were permitted opportunities to share their written observations about the study as well.

Students were offered follow-up use of materials used in this study, particularly those available for the control group that included both the Thinker's Guides and the Rationale program on computer. There were 31 students who elected to engage in follow-up use of materials. All follow-up use of materials was for use in the Tutoring Center.

Statistical Analyses

Research Questions and Hypotheses

As a review, the research questions for this study were as follows:

1. Does direct instruction in critical thinking skills using the Thinker's Guides or Rationale, as a supplement to content course tutoring, improve the critical thinking skills and academic achievement of Freshmen who are repeating a course, as measured by the California Critical Thinking Skills Test-2000 Post-test Total Scores and final course grades to a greater extent than content course tutoring alone?
2. Do abstract reasoning and critical thinking skills, as measured by the Computer Category Test – Research Edition and the California Critical Thinking Skills Test – 2000 predict final grade outcome in repeated courses for freshman students who are repeating courses?

3. Are there significant differences between Experimental Group 1, Experimental Group 2 or the Control Group on the California Critical Thinking Skills Test – 2000 Analysis, Evaluation, Inference, Deductive Reasoning, and Inductive Reasoning Subscales?
4. Is there a significant difference in the critical thinking skills and academic achievement of males vs. females following direct instruction in critical thinking skills using the Thinker's Guides or Rationale as measured by the California Critical Thinking Skills Test Post-test Total Ranked Scores, CCTST-2000 Subscale Scores, and final grade?
 1. Hypothesis H₁: - Group 3 (Control Group) will demonstrate significantly lower critical thinking and academic achievement than Groups 1 (Thinker's Guides) or 2 (Rationale).
 2. Hypothesis H₂: - There will be a significant difference between the CAT:CV Error Score and students' final grades in repeat courses and between the CCTST – 2000 Post- test Total score and students' final grades in repeat courses.
 3. Hypothesis H₃ – Experimental Group 1 will demonstrate significantly higher scores than Experimental Group 2 and 3 on the CCTST-2000 Analysis, Evaluation, Inference, Deductive Reasoning and Inductive Reasoning Subscales.
 4. Hypothesis H₄ - Males will demonstrate significantly higher scores on the CCTST – 2000 Post-test Total Ranked Score, CCTST-2000 Post-test Subscale Scores, and final grades than females.

Table 4

Research Questions, Hypotheses, Variables, Statistical Analysis, and Statistical Assumptions for the Direct Instruction in Critical Thinking Skills Study

<u>Research Questions</u>	<u>Hypotheses</u>	<u>Variables</u>	<u>Statistic</u>	<u>Assumptions</u>	<u>Assumptions Appropriateness</u>
1. Does direct instruction in critical thinking skills using the Thinker's Guides or Rationale, as a supplement to content course tutoring, improve the critical thinking skills and academic achievement of freshmen who are repeating a course, as measured by the California Critical Thinking Skills Test Post-test Total Score and final course grades, to a greater extent than use of content course tutoring alone?	Group 3 (control group) will demonstrate significantly lower critical thinking and academic achievement than groups 1(Thinkers' Guides) or 2 (Rationale).	CCTST scores Tutoring Final grade	MANCOVA Tukey HSD ANOVA - Block-set	1. Interval or Ratio data 2. Normality for each group 3. Equal Variances 4. Homogeneity of Covariances 1. Independence 2. Normally Distributed 3. Equal Variances	1. Examine Instruments 2. Normal Curve Histogram 3. Descriptive Statistics 4. Scattergram Inspection 1. Correlations 2. Normal Curve Histogram 3. Descriptive Statistics
2. Do abstract reasoning and critical thinking skills, as measured by the CAT:CV Error score and the CCTST -2000 Post-test Total Ranked Score predict final grade outcomes in repeated courses for Freshman students who are repeating courses?	There is a significant relationship between the CAT:CV Error Score and students' final grades in repeat courses and between the CCTST-2000 Post- test Total Ranked Score and students' final grades in repeat courses.	CAT:CV Error Score CCTST Final grade	Linear Regression	1. Interval or Ratio data 2. Linearity 3. Errors are normally distributed 4. Errors are randomly distributed around the mean of zero	1. Examine Instruments 2. Inspect scattergram 3. Examine error plots 4. Examine Error plots

Table 4 (Continued)

Research Questions, Hypotheses, Variables, Statistical Analysis,, and Statistical Assumptions for the Direct Instruction in Critical Thinking Skills Study

<u>Questions</u>	<u>Hypotheses</u>	<u>Variables</u>	<u>Statistic</u>	<u>Assumptions</u>	<u>Assumptions Appropriateness</u>
3. Are there significant differences between Experimental Group 1, Experimental Group 2, or the Control Group on the CCTST-2000 Post-test Analysis, Evaluation, Inference, Deductive Reasoning, and Inductive Reasoning Subscales?	Experimental Group 1 will demonstrate significantly higher scores than Experimental Group 2 or the Control Group on the CCTST – 2000 Post-test Analysis, Evaluation, Inference, Deductive Reasoning, and Inductive Reasoning Subscales.	CCTST subtest scales Ranked scores	MANOVA	1. Interval or Ratio data 2. Equal Variances 3. Normality for each group 4. Linearity	1. Examine Instrument 2. Descriptive Stats 3. Normal Curve Histogram 4. Visual Inspection of Scattergram
4. Is there a significant difference in the critical thinking skills and academic achievement of males vs. females following direct instruction in critical thinking skills using the Thinker’s Guides or Rationale as measured by the California Critical Thinking Skills Test Post-test Total Score, CCTST-2000 Subscale Scores, and final grade?	Males will demonstrate significantly higher scores on the CCTST - 2000 Post-test Total Ranked Score, the CCTST-2000 Post-test Subscale Scores, and final grades than females.	CCTST post-test total scores	ANCOVA MANCOVA ANOVA	1. Interval or Ratio data 2. Normality for each group 3. Equal Variances 4. Homogeneity of Covariances	1. Examine Instruments 2. Normal Curve Histogram 3. Descriptive Statistics 4. Scattergram Inspection

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS Base 16.0, 2008). To address Question 1, SPSS was used to conduct a Multivariate Analysis of Covariance (MANCOVA) on the effect of treatment group on the CCTST-2000 Post-test Total Ranked Scores and students' final grades. All assumptions for the use of MANCOVA were met. All group data were examined for outliers. Three outliers were identified in Group 1 and removed from the analysis. A Block-Set Analysis of Variance (ANOVA) was run to determine the effect of Block-Set on the CCTST-2000 Pre-test Total Rank to determine if subjects started out at the same level since those who completed eligibility criteria first were the first to be filled in block sets of three (Experimental 1, Experimental 2, or Control Group). A Multiple Linear Regression analysis was conducted after the removal of one data point as an outlier to determine the predictability of the CAT:CV on students' final grades. Once removed, data met all assumptions for normality, linearity, etc. A Multivariate Analysis of Variance (MANOVA) was conducted to determine which treatment group demonstrated significant differences on the CCTST-2000 Subscale Scores. An Analysis of Covariance (ANCOVA) was conducted to determine the effect of sex on the CCTST-2000 Post-test Total Ranked Scores. A MANCOVA was conducted to determine the effect of sex on the CCTST-2000 Post-test Subscale Scores. Finally, an ANOVA was conducted to determine the effect of sex on students' final grades.

Each semester, grade performance of students receiving tutoring services is recorded by graduate assistants from BannerWeb, a university data base. The graduate assistants recorded grades for participants in this study, which also reduced any perceived conflict with the role of Director of the Tutoring Center who was also the researcher for this study. Grade performance for each student participant was reported to the Director.

The Director does not generate information about students. It is a clerical job done by graduate students for statistical purposes alone.

To ensure confidentiality, participants were given identification numbers generated by the graduate assistants working on this study. Only the graduate assistants had access to additional identifying information.

Graduate assistants set up and proctored pre-testing and post-testing. Upon completion of the tests, results were sent directly to Insight Assessment, where test scores were calculated and provided in computer generated reports. Insight Assessment is a testing company that sells and evaluates the California Critical Thinking Skills Test.

Reports were generated directly from Insight Assessment to reduce human error and to minimize any dual-role conflict. Reports provided by Insight Assessment included a calculation of overall and sub-scale scores for each test-taker by identification number, basic descriptive statistics for the entire group of test-takers, and descriptive statistics based on variables such as age, gender, ethnicity and class level.

Summary

The purpose of this study was to determine if direct instruction in critical thinking skills could improve the critical thinking and academic achievement of freshmen students' who were repeating courses. Tutoring at the post-secondary level has been reported by researchers as a tool for success for Freshman students, but insufficient for students possessing inadequate critical thinking skills. Subjects were identified by the Registrar at a rural Pennsylvania university as those who repeated courses one or more times and informed about this study.

Initially, 143 students volunteered for this study. Eligibility criteria were developed to select subjects for this study that reduced the number of volunteers to 129. Subjects who did not complete all facets of this study further reduced the number of subjects to 98 who completed the study in its entirety. Due to the variability in student performance that may have been related to education level, 20 non-freshmen were removed for data analysis.

The Computer Version of the Category Test – Research Edition was used to screen students for abstract reasoning and problem solving skills and the California Critical Thinking Skills Test (CCTST) Form 2000 was used as a pre-test and post-test measure. The Thinker's Guides and Rationale Argument Mapping Program were used as treatment interventions for 13 weeks. Subjects' final grades in the repeated courses were used to determine their academic achievement following intervention.

Data were analyzed using ANCOVA, MANOVA, MANCOVA, and Multiple Linear Regression to determine if significant differences occurred in CCTST post-

test total, CCTST subscale scores, and final grades based on treatment intervention and sex. Data analysis was also conducted to determine the ability of the Category Test error score to predict students' final grades.

CHAPTER FOUR

RESULTS

Introduction

The purpose of this study was to evaluate the effect of direct instruction using two critical thinking programs on the critical thinking and academic achievement of Freshmen repeating courses. In addition, the study was designed to determine if tutoring alone would result in improved academic achievement and the development of critical thinking skills. Researchers have not reached a consensus about whether critical thinking skills should be taught through discipline specific or stand alone courses in critical thinking or which tools should be used.

This study used the Thinker's Guides and Rationale Argument Mapping program to improve subjects' critical thinking. The Thinker's Guides are based on Richard Paul's model of critical thinking and developed by Richard Paul and Linda Elder for use with college students. Rationale, developed by Tim van Gelder, is a computer program that is designed for use with college students to improve critical thinking through argument mapping. The California Critical Thinking Skills Test – Form 2000 is a measure of critical thinking and was used as a pre-test and a post- test measure because it is designed for use with post-secondary students and addresses specific skills of good critical thinkers that were identified by the Delphi Report. Subjects were randomly assigned to Experimental Group 1 (Thinker's Guides), Experimental Group 2 (Rationale), or

the Control Group. The impact of gender on subject performance was also studied.

Complications

There were minor complications during this study. Several students were not present during the scheduled post-testing session. Five students had to be post-tested individually by graduate assistants. Twenty-six students either failed to return for post-testing or failed to reschedule missed sessions and were removed from this study. The original sample of 98 was reduced to 78 to include only Freshman students. This resulted in uneven group sizes that may have complicated results.

Computer Program

The Statistical Package for the Social Sciences (SPSS) Base 16.0 (2008) was used to analyze data in this study.

Analysis

Research questions, hypotheses and data analysis for this study are included in this chapter.

1. Does direct instruction in critical thinking skills using the Thinker's Guides or Rationale, as a supplement to content course tutoring, improve the critical thinking skills and academic achievement of Freshmen who repeat courses, as measured by the California Critical Thinking Skills Test- 2000 Post-test Total Ranked Score and final course grades, to a greater extent than content course tutoring alone? Hypothesis H₁: - Group 3 (Control Group) will demonstrate

significantly lower critical thinking and academic achievement than Groups 1 (Thinker's Guides) and Group 2 (Rationale).

The independent variable used to address this question was the treatment intervention to determine which intervention significantly affected the students' CCTST-2000 Post- test Total Ranked Score and final grades. The CCTST-2000 Post-test Total Ranked Score and final grade served as dependent variables. Data was analyzed using a Multiple Analysis of Covariance (MANCOVA) with the CCTST-2000 Pre-test Total Ranked Score as the covariate. Box's M test of normality was used to test the null hypothesis that the observed covariance matrices of the dependent variables were equal across groups. Levene's Test of Equality of Error Variances was conducted to test the null hypothesis to determine that the error variance of the dependent variable was equal across groups. The Kolmogorov-Smirnov goodness-to-fit test and the Shapiro-Wilk test were used to further examine the sample populations for normal distribution.

Analyses revealed that the intervention group did not significantly affect subjects' CCTST-2000 Post-test Total Ranked Score $F(2, 71) = .45; p = .634$. Therefore, the null hypothesis could not be rejected. Other factors such as previous exposure to critical thinking instruction, hours of tutoring and studying per week, etc. were not controlled for and may have affected results. However, intervention group revealed a significant effect on subjects final grade, $F(2, 71) = 7.54; p = .001$.

Post hoc tests for multiple comparisons were conducted using the Tukey HSD statistic to determine where differences occurred. Tukey HSD revealed

statistically significant differences in final grade between groups 1 (Thinker's Guides) and 3 (Control Group).

Further analyses were conducted to determine the observed power and effect size for MANCOVA. Examining Wilk's Lambda, the observed power was .91, but the effect size was small (Partial Eta Squared = .11) for the model. This suggests that sample size may not have been adequate. Further power analysis and effect size calculations revealed a power of .94 and an effect size of .18 (Partial Eta Squared) for the effect of Group on Final grade and a power of .12 and effect size of .01 (Partial Eta Squared) for the effect of Group on the CCTST-2000 Post-test Total Ranked Score. Table 5 illustrates these findings.

Table 5

Multiple Analysis of Covariance for the Affect of Group on the CCTST-2000 Post-test Total Ranked Score and Final Grade

DESCRIPTIVE STATISTICS -----											
<u>GROUPS</u>	<u>Instrument</u>	<u>n</u>	<u>Covariates</u>			<u>CCTST-2000 Post-test Total Score</u>			<u>Final Grade</u>		
			<u>Mean</u>	<u>S.D.</u>	<u>Range</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>
Thinker's Guides	CCTST-2000 Pre-	22	10.0	2.0	2 - 24						
	CCTST-2000 Post-	22				40.0	24.9	2 - 79	3.0	.5	0 - 4
Rationale	CCTST-2000 Pre-	25	10.2	2.9	.1 - 46						
	CCTST-2000 Post-	25				36.7	23.2	.1 - 88	2.6	.7	1 - 4
Control Group	CCTST-2000 Pre-	28	10.8	3.1	.8 - 68						
	CCTST-2000 Post-	28				38.9	26.4	2 - 84	2.3	.8	.7 - 4

MULIVARIATE ANALYSIS OF COVARIANCE-----

Tests of Equality of Covariance Matrices for Final Grade-----

Method	Kolmogorov-Smirnov(a)			Shapiro-Wilk		
	<u>Statistic</u>	<u>df</u>	<u>Sig.</u>	<u>Statistic</u>	<u>df</u>	<u>Sig.</u>
Thinker's Guides	.148	22	.200	.927	22	.108
Rationale	.133	25	.200	.967	25	.561
Control	.128	28	.200	.966	25	.476

Table 5 (Continued)

Multiple Analysis of Covariance for the Affect of Group on the CCTST-2000 Post-test Total Ranked Score and Final Grade

Tests of Equality of Covariance Matrices for CCTST-2000 Post-test Total Ranked Score-----

<u>Method</u>	<u>Kolmogorov-Smirnov</u>			<u>Shapiro-Wilk</u>		
	<u>Statistic</u>	<u>df</u>	<u>Sig.</u>	<u>Statistic</u>	<u>df</u>	<u>Sig.</u>
Thinker's Guides	.147	25	.169	.955	25	.321
Rationale	.159	25	.104	.953	25	.295
Control	.144	28	.143	.911	25	.021

Test of Impact of Covariates (EFFECT...Group)

<u>Test Name</u>	<u>Value</u>	<u>Approx. F</u>	<u>Hypothesis df</u>	<u>Error df</u>	<u>p</u>
Pillais	.187	8.05	2.00	70.00	.001
Wilk's Lambda	.813	8.05	2.00	70.00	.001
Hotelling	.230	8.05	2.00	70.00	.001
Roy's	.230	8.05	2.00	70.00	.001

Table 5 (Continued)

Multiple Analysis of Covariance for the Affect of Group on the CCTST-2000 Post-test Total Ranked Score and Final Grade

Univariate F-tests with (2,70) df

<u>Variable</u>	<u>Hypothesis MS</u>	<u>Error MS</u>	<u>F</u>	<u>p</u>
Final Grade	8.4	4.2	7.54	.001
CCTST-2000 Post-test Total	472.6	236.3	.45	.634

POST-HOC PROCEDURES-----

Tukey HSD Post-Hoc Test for Impact of Group on Final Grade-----

<u>Intervention Group</u>	<u>Intervention Group</u>	<u>Mean Difference</u>	<u>Std. Error</u>	<u>Sig.</u>
Thinker's Guides	Rationale	.4	.16	.032
	Control Group	.7	.15	<.001
Rationale	Thinker's Guides	-.4	.16	.032
	Control Group	.3	.15	.063
Control Group	Thinker's Guides	-.7	.15	<.001

2. Do abstract reasoning and critical thinking skills, as measured by the Category Test – Computer Version (CAT:CV) and the California Critical Thinking Skills Test – 2000 predict final grade outcomes in repeated courses for Freshman students who are repeating courses? Hypothesis H₂: – There will be a significant relationship between the CAT:CV Error Score and students' final grades in repeat courses and between the CCTST-2000 Post- test Total Score and students' final grades in repeat courses.

A Multiple Linear Regression analysis was conducted to address both parts of this question. The predictors for this analysis were the Category Test Error Score and the CCTST-2000 Post-test Total Ranked Score. Final grade was the dependent variable. Results revealed a significant relationship between the CAT:CV and final grade. Due to the relatively small sample size for this study, the adjusted R Square of .366 was used because it takes into account the number of predictors. Based on this analysis, 36.6% of the variation in the dependent variable (final grade) was explained by this model. Therefore, the null hypothesis that there is no significant relationship between the CAT:CV error score and final grade was rejected.

Following the analysis of data, Beta weights for predictor variables were inspected to determine which independent variable contributed more significantly to final grade. Results revealed that both the Category Test Error Score (Beta - .425) and the CCTST-2000 Post-test Total Ranked Score (Beta -.267) provided unique and significant contributions to final grade. However, the Category Test Error Score demonstrated a larger contribution (11.97%) compared to the

CCTST-2000 Post- test Total Ranked Score (4.75%) on the total variance of the dependent variable (final grade). The null hypothesis that there is no significant relationship between the CAT:CV and the CCTST-2000 Post-test Total Ranked Score was rejected. Power analysis and effect size for the regression analysis was conducted using SPSS that revealed a power of .99 and an effect size of .36. Table 6 illustrates these findings.

Table 6

Multiple Regression Predicting Final Grade using the Category Test: Computer Version- Research Edition Error Score and the CCTST-2000 Post-test Total Ranked Score

DESCRIPTIVE STATISTICS-----					
<u>Variable</u>	<u>n</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>	
CAT:CV Error Score	73	36.2	14.9	26-130	
CCTST-2000 Post-Total Correct	73	14.5	4.1	3-23	
REGRESSION-----					
<u>Model Fit</u>	<u>R²</u>	<u>R² Adj.</u>			
F [2,73] = 22.03; p = <.001	.38	.36			
<u>Variables in Equation</u>	<u>B</u>	<u>SE B</u>	<u>b</u>	<u>t</u>	<u>p</u>
CCTST-2000 Post-Total	.054	.05	.26	2.34	.022
CAT:CV Error Score	-.03	.01	-.42	-3.71	<.001

3. Are there significant differences between Experimental Group 1, Experimental Group 2 or the Control Group on the California Critical Thinking Skills Test – 2000 Analysis, Evaluation, Inference, Deductive Reasoning, and Inductive Reasoning Subscales? Hypothesis H₃: - Group 1 will demonstrate significantly higher scores than Experimental Group 2 and the Control Group 3 on the CCTST- 2000 Subscales.

A Multiple Analysis of Variance (MANOVA) was run to determine which group made the most significant contribution to the change in CCTST-2000 Post-test Subscale Scores. Results did not show a significant effect of intervention group on CCTST-2000 Post-test Subscale Scores $F(10,140) = .61, p = .798$. Therefore, the null hypothesis was not rejected. (See Table 7)

Table 7

Multivariate Analysis of Variance for the Affect of Group on the Change in the CCTST-2000 Post-test Subscale Scores

DESCRIPTIVE STATISTICS			Change in CCTST-2000 Post-test Subscale Scores			
INTERVENTION METHOD	PRACTICE	<u>n</u>		<u>Mean</u>	<u>S.D.</u>	<u>Range</u>
Thinker's Guides	13 wk. (1.5 hr./wk)	25	Change in deductive score	2.6	2.7	1-12
			Change in inductive score	1.8	2.0	4-13
			Change in inference score	2.6	2.4	1-5
			Change in analysis score	.8	1.2	1-6
			Change in evaluation score	1.2	1.6	1-7
			Total	1.8	1.9	1-13
Rationale	13 wk. (1.5 hr./wk)	25	Change in deductive score	2.1	2.2	2-12
			Change in inductive score	1.9	2.8	1-11
			Change in inference score	2.5	2.8	2-13
			Change in analysis score	.7	1.2	1-5
			Change in evaluation score	.8	2.1	1-6
			Total	1.6	2.2	1-13
Control Group	13 wk. (1.5 hr./wk)	27	Change in deductive score	1.6	2.1	4-11
			Change in inductive score	2.1	2.8	2-13
			Change in inference score	2.2	2.5	1-11
			Change in analysis score	.5	1.5	1-6
			Change in evaluation score	.9	1.4	1-7
Total		77	Total	1.7	2.0	1-13

Table 7 (Continued)

Multivariate Analysis of Variance for the Affect of Group on the Change in the CCTST-2000 Post-test Subscale Scores

MULTIVARIATE ANALYSIS OF VARIANCE-----

Multivariate Tests of Significance

INTERVENTION GROUP EFFECT ON CCTST-2000 Post-test Subscale Score-----

METHOD

<u>Test Name</u>	<u>Value</u>	<u>F</u>	<u>Hypoth. df</u>	<u>Error df</u>	<u>p</u>
Pillai's Trace	.083	.61	10.0	142.0	.799
Wilks' Lambda	.917	.61	10.0	140.0	.798
Hotelling's Trace	.089	.61	10.0	138.0	.797
Roy's Largest Root	.083	1.18	5.0	71.0	.328

4. Is there a significant difference in the critical thinking skills and academic achievement of males vs. females following direct instruction in critical thinking using the Thinker's Guides or Rationale as measured by the California Critical Thinking Skills Post-test Total Ranked Score, CCTST-2000 Post-test Subscale Scores, and final grades? Hypothesis H₄: - Males will demonstrate significantly higher scores on the CCTST- 2000 Post-test Total Score, CCTST-2000 Post – test Subscale Scores, and final grade than females.

An Analysis of Covariance (ANCOVA), Multivariate Analysis of Covariance (MANCOVA), and an Analysis of Variance (ANOVA) were used to analyze data to answer question four. Sex was not a significant factor in the CCTST-2000 Post-test Total Ranked Score $F(1, 74) = .14; p = .703$, the CCTST-2000 Post-test Ranked Subscale Scores, $F(5, 67) = 1.30; p = .271$ or for final grade $F(1, 72) = 1.07; p = .304$. Therefore, the null hypothesis was not rejected. Tables 8, 9, and 10 illustrate these findings. Analyses of observed power and effect size for sex for the CCTST-2000 Post-test Total Ranked Score, the CCTST-2000 Post-test Total Ranked Subscale Scores, and final grade revealed observed power of .07 and effect size of .002 for the CCTST-2000 Post- test Total Ranked Score, observed power of .17 and effect size of .03 for the CCTST-2000 Post-test Ranked Subscale Scores, and observed power of .18 and effect size of .02 for final grade. Figures 13, 14, and 15 illustrate final grade achievement in repeated courses for all groups following direct instruction in critical thinking. In the analysis of final grade, three outliers from Group 1 were removed for the analysis. Tests for normalcy were conducted prior to the analysis.

Table 8

Analysis of Covariance to Determine the Affect of Sex on the CCTST-2000 Post-test Total Ranked Scores

DESCRIPTIVE STATISTICS-----

Sex	<u>n</u>	CCTST-2000 Post-test Total		
		<u>Mean</u>	<u>S.D.</u>	<u>Range</u>
Male	33	38.4	26.9	2 - 84
Female	44	37.7	22.9	.1 - 88
Total	77	38.0	24.5	.1 - 88

ANALYSIS OF COVARIANCE-----

<u>Source of Variation</u>	<u>Sum of Squares</u>	<u>df</u>	<u>Mean Square</u>	<u>F</u>	<u>p</u>
CCTST-2000 Pre-percentile Rank	8296.1	1	8296.1	16.38	<.001
Sex	74.4	1	74.1	.14	.703
Residual	37463.6	74	506.2		

Table 9

Multiple Analysis of Covariance to Determine the Affect of Sex on the CCTST-2000 Post-test Subscale Scores

DESCRIPTIVE STATISTICS-----								
<u>Sex</u>	<u>CCTST-2000 Subscales</u>	<u>CCTST-2000 Pre-test Subscale Scores</u>				<u>CCTST-2000 Post-test Subscale Scores</u>		
		<u>n</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>	<u>Mean</u>	<u>S.D.</u>	<u>Range</u>
Male	Pre-deductive Score	33	4.7	1.5	1-8			
	Post-deductive Score	33				6.6	2.4	1-12
Female	Pre-deductive Score	44	4.9	1.9	1-10			
	Post-deductive Score	44				7.3	2.3	2-12
Male	Pre-inductive Score	33	5.3	2.1	2-13			
	Post-inductive Score	33				7.7	2.8	2-13
Female	Pre-inductive Score	44	5.5	2.1	0-11			
	Post-inductive Score	44				7.3	2.1	2-13
Male	Pre-inference Score	33	4.6	1.5	2-8			
	Post-inference Score	33				7.0	2.6	1-11
Female	Pre-inference Score	44	4.7	1.5	1-8			
	Post-inference Score	44				7.2	2.3	2-13
Male	Pre-analysis Score	33	2.7	1.3	1-5			
	Post-analysis Score	33				3.3	1.2	1-6
Female	Pre-analysis Score	44	2.9	1.4	0-6			
	Post-analysis Score	44				3.6	1.1	1-6
Male	Pre-evaluation Score	33	2.8	1.4	1-7			
	Post-evaluation Score	33				4.0	1.7	1-7
Female	Pre-evaluation Score	44	2.9	1.4	1-6			
	Post-evaluation Score	44				3.8	1.5	0-6

Table 9 (Continued)

Multiple Analysis of Covariance to Determine the Affect of Sex on the CCTST-2000 Post-test Subscale Scores

Multivariate Tests-----

<u>Effect</u>		<u>Value</u>	<u>F</u>	<u>Hypothesis df</u>	<u>Error df</u>	<u>Sig.</u>	<u>Partial Eta Squared</u>
Dedc_pre	Pillai's Trace	<.001	.a	.0	.0		
	Wilks' Lambda	1.00	.a	.0	69.0		
	Hotelling's Trace	<.001	.a	.0	2.0		
	Roy's Largest Root	<.001	.00	5.0	66.0	1.00	<.001
Indc_pre	Pillai's Trace	<.001	.a	.0	.0		
	Wilks' Lambda	.00	.a	.0	69.0		
	Hotelling's Trace	<.001	.a	.0	2.0		
	Roy's Largest Root	<.001	.00	5.0	66.0	1.00	<.001
Infr_pre	Pillai's Trace	<.001	.a	.0	.0		
	Wilks' Lambda	1.00	.a	.0	69.0		
	Hotelling's Trace	<.001	.a	.0	2.0		
	Roy's Largest Root	<.001	.00	5.0	66.0	1.00	<.001
Anl_pre	Pillai's Trace	<.001	.a	.0	.0		
	Wilks' Lambda	1.00	.a	.0	69.0		
	Hotelling's Trace	<.001	.a	.0	2.0		
	Roy's Largest Root	<.001	.00	5.0	66.0	1.00	<.001
Evl-pre	Pillai's Trace	<.001	.a	.0	.0		
	Wilks' Lambda	1.00	.a	.0	69.0		
	Hotelling's Trace	<.001	.a	.0	2.0		
	Roy's Largest Root	<.001	.00	5.0	66.0	1.00	<.001
Sex	Pillai's Trace	.08	1.30 ^a	.0	67.0	.271	.089
	Wilks' Lambda	.91	1.30 ^a	.0	67.0	.271	.089
	Hotelling's Trace	.09	1.30 ^a	.0	67.0	.271	.089
	Roy's Largest Root	.09	1.30 ^a	5.0	67.0	.271	.089

a. Exact Statistic

Table 9 (Continued)

Multiple Analysis of Covariance to Determine the Affect of Sex on the CCTST-2000 Post-test Subscale Scores

Note. Abbreviations for the CCTST-2000 Subscales are as follows: Dedc_pre – CCTST-2000 Pre-test Deductive Reasoning Subscale, Indc_pre – CCTST-2000 Pre-test Inductive Reasoning Subscale, Infr_pre – CCTST-2000 Pre-test Inference Subscale, Anl_pre – CCTST-2000 Pre-test Analysis Subscale, and Evi-pre –CCTST-2000 Evaluation Subscale.

Table 10

Analysis of Variance to Determine the Affect of Sex on Final Grade

DESCRIPTIVE STATISTICS-----

<u>SEX</u>	<u>n</u>	<u>GRADE</u>		
		<u>Mean</u>	<u>S.D.</u>	<u>Range</u>
Male	31	2.5	.8	0.0 – 4.0
Female	43	2.7	.7	1.0 – 4.0

ANALYSIS OF VARIANCE-----

<u>Source of Variation</u>	<u>df</u>	<u>Mean Square</u>	<u>F</u>	<u>n²</u>	<u>p</u>
SEX	1	.7	1.07	.02	.304
Residual	72	.6			

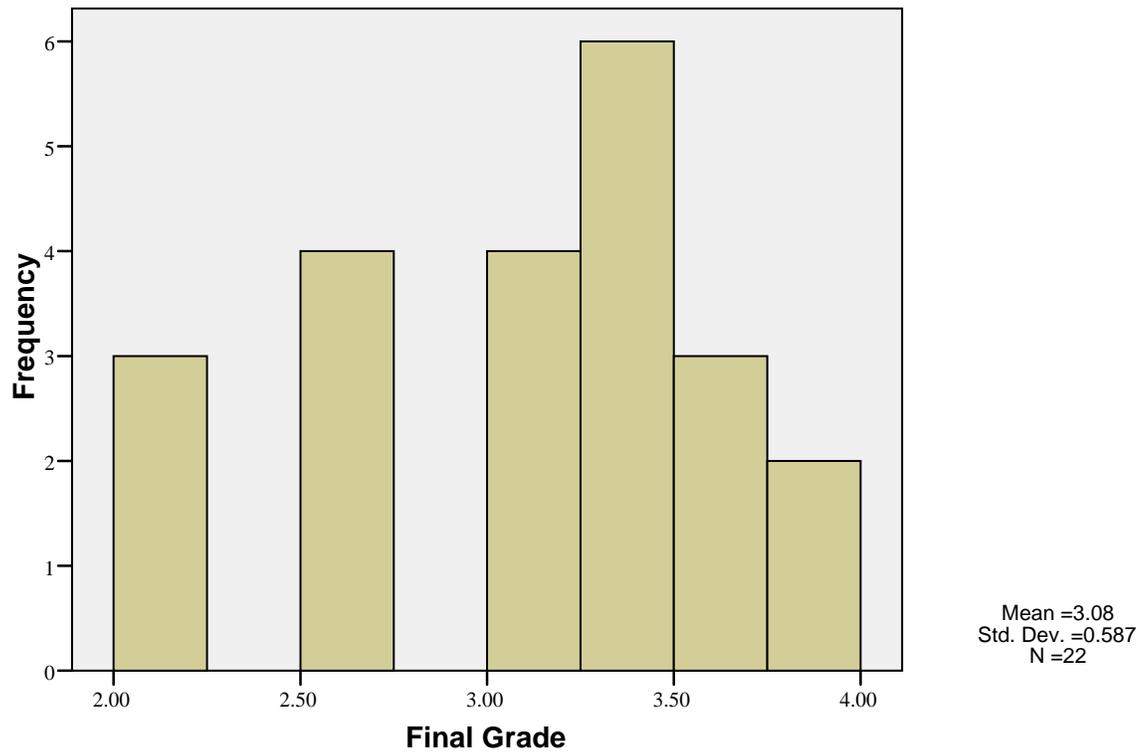


Figure 13. Final grade achievement by Group 1 (Thinker's Guides).

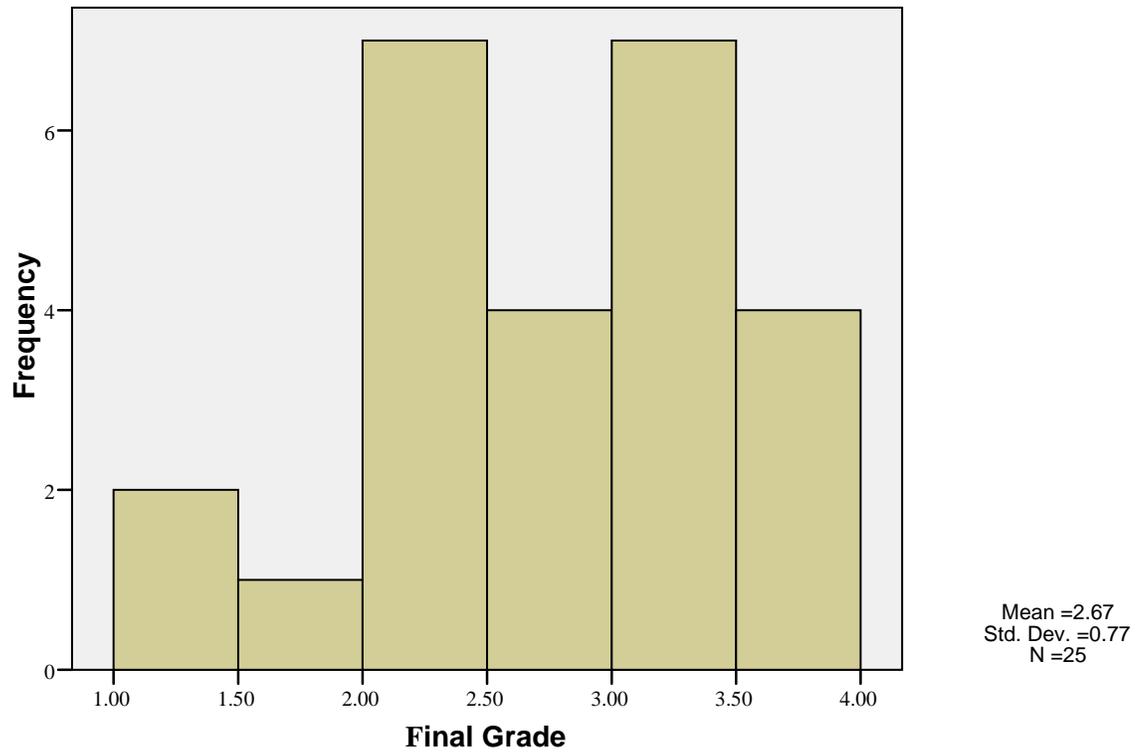


Figure 14. Final grade achievement by Group 2 (Rationale).

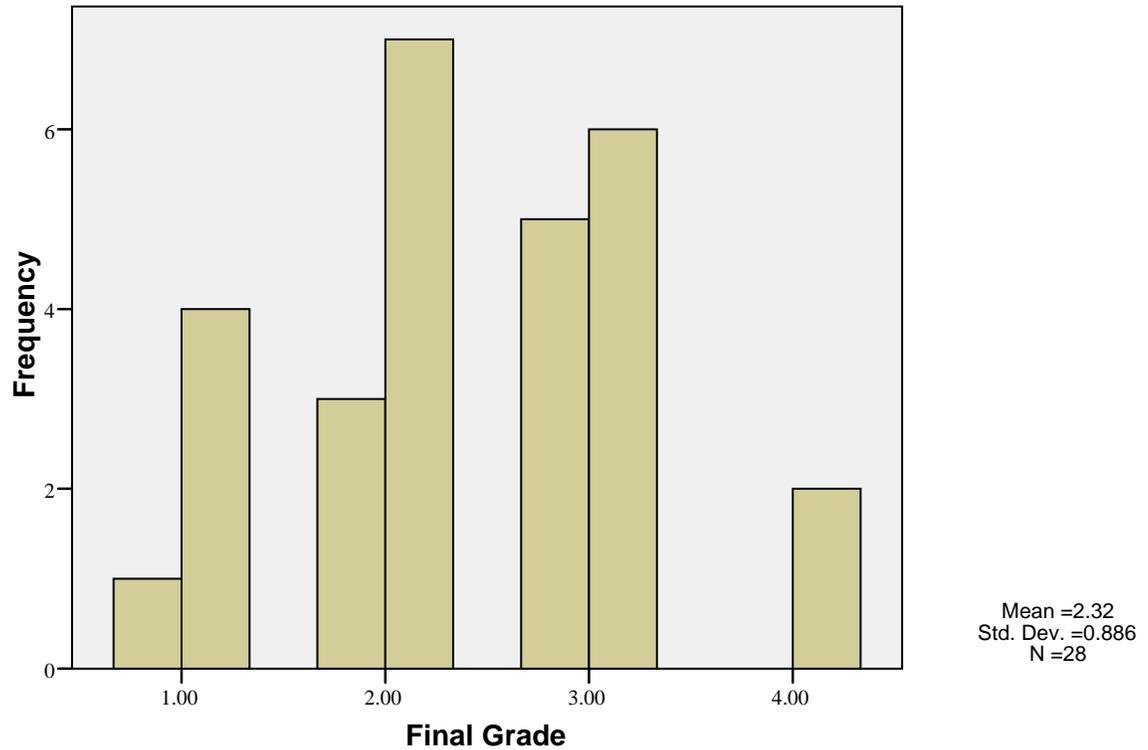


Figure 15. Final grade achievement by the Control Group.

Finally, an analysis using a Block Set ANOVA was conducted to determine the relationship of pre-intervention critical thinking skills of subjects in this study even though MANCOVA should have equalized all subjects based on this covariate. Results revealed a significant relationship between the block design and the pre-intervention critical thinking skills of subjects that were measured by the CCTST-2000 Pre-test Total Ranked Score. Results revealed a significant $F(30, 46) = 2.28$; $p = .006$ and an observed power and effect size of .99 and .59 respectively. (See Table 11)

Table 11

Block Set Analysis of Variance to Determine the Relationship between Block Design and the Equality of Subjects at Pre-intervention

DESCRIPTIVE STATISTICS-----

<u>BLOCK-SET</u>	<u>n</u>	<u>SCORE</u>		
		<u>Mean</u>	<u>S.D.</u>	<u>Range</u>
2.00	1	68.0		68.0-68.0
3.00	1	12.0		12.0-12.0
5.00	3	3.7	3.9	.1- 8.0
6.00	1	24.0		24.0-24.0
7.00	3	22.3	9.6	12.0-31.0
8.00	3	10.6	2.3	8.0-12.0
9.00	3	28.3	19.1	8.0-46.0
10.00	3	27.0	13.4	12.0-38.0
11.00	3	14.6	11.3	2.0-24.0
12.00	1	3.0		3.0- 3.0
13.00	2	8.0	0.0	8.0- 8.0
14.00	3	6.3	2.8	3.0- 8.0
15.00	2	3.5	2.1	2.0- 5.0
16.00	3	8.3	8.5	2.0-18.0
17.00	3	4.0	1.7	2.0- 5.0
18.00	2	4.0	1.4	3.0- 5.0
19.00	3	7.6	4.5	3.0-12.0
20.00	3	18.0	6.0	12.0-24.0

Table 11 (Continued)

Block Set Analysis of Variance to Determine the Relationship between Block Design and the Equality of Subjects at Pre-intervention

<u>BLOCK-SET</u>	<u>n</u>	<u>SCORE</u>			
		<u>Mean</u>	<u>S.D.</u>	<u>Range</u>	
21.00	3	9.6	7.6	3.0-18.0	
22.00	3	6.6	4.7	3.0-12.0	
23.00	2	2.0	0.0	2.0- 2.0	
24.00	1	18.0		18.0-18.0	
25.00	3	17.0	24.8	3.0-46.0	
26.00	3	7.6	4.5	3.0-12.0	
27.00	3	14.6	8.3	8.0-24.0	
28.00	3	10.3	6.8	5.0-18.0	
29.00	3	10.9	11.8	.8-24.0	
30.00	3	4.8	6.2	.4-12.0	
31.00	3	30.0	24.5	5.0-54.0	
32.00	2	10.0	2.8	8.0-12.0	
33.00	2	16.0	11.3	8.0-24.0	
<u>ANALYSIS OF VARIANCE</u>					
<u>Source of Variation</u>	<u>df</u>	<u>Mean Square</u>	<u>F</u>	<u>n²</u>	<u>p</u>
BLOCK SET	30	259.6	2.28	.59	.006
Residual	46	113.7			

Summary

The analyses for this study examined the effect of direct instruction on the critical thinking skills and academic achievement of Freshmen attending a rural southeastern university in Pennsylvania who were being tutored in courses they were repeating. The relationship of sex on subjects' critical thinking skills and academic achievement was also examined.

There were complications for this study that included the removal of 20 non-freshmen and those who did not complete the entire study. This reduction in subjects resulted in a small sample size of 78. Additionally, the Block design used to randomly assigned students demonstrated a large effect size that suggests students were not equal in critical thinking at the start of this study. The Statistical Package for the Social Sciences (SPSS base, 16.0, 2007) was used to analyze data for this study.

MANCOVA was conducted to determine the effect of intervention group (Thinker's Guides or Rationale) on subjects' post-test scores in critical thinking based on the CCTST-2000 and academic achievement measured by final grade in a repeated course. Examining Wilk's Lambda, MANCOVA results revealed that intervention group was not a factor in subjects' post-test critical thinking scores, $F(2, 70) = .43$; $p = .652$. However, intervention group did show a statistically significant relationship with subjects' final grades, $F(2, 70) = 7.73$; $p = .001$. Power analysis revealed .94 observed power, but a small effect size (.18). Tutoring was not the only factor contributing to students' final grades.

Multiple Linear Regression was conducted to determine the extent to which the CAT:CV and the CCTST – 2000 Post-test Total Ranked Score could predict subjects' final grades. Regression analysis revealed a significant relationship between the CAT:CV and CCTST-2000 Post-test Total Ranked Scores and subjects' final grades. Using the adjusted R Square (.366), 36.6% of the variation in final grade was explained by the model with an observed power of .99. Since both the CAT:CV and the CCTST-2000 Post-test Total Ranked Scores revealed significant relationships with final grades. Therefore, Beta weights were examined and revealed that the CAT:CV contributed more significantly to subjects' final grades (Beta = -.425), $t = -3.71$, $p = .000$ than the CCTST – Form 2000 Post-test Total Ranked Scores (Beta = .267), $t = 2.34$; $p = .022$ or 11.97% and 4.75% respectively.

A MANOVA was conducted to determine which group had a significant effect on the CCTST-2000 Post-test Total Ranked Subscale Scores. It was hypothesized that Group 1 (Thinker's Guides) would demonstrate a more significant effect than Groups 2 (Rationale) or Group 3 (Control). The results of MANOVA did not show any significant relationship. Examining Wilk's Lambda, results revealed an $F(10, 140) = .61$; $p = .798$. Therefore, the null hypothesis was not rejected.

Finally, data were analyzed with ANCOVA, MANCOVA, and ANOVA to determine the effect of sex on CCTST-2000 Post-test Total Ranked Score, the CCTST-2000 Post-test Ranked Subscale Scores, and final grade. All analyses revealed no significant effect of sex, even though males were originally

hypothesized to show greater performance following instruction in critical thinking. Data analysis revealed ANCOVA $F(2, 77) = .14; p = .703$, MANCOVA $F(5, 67) = 1.30; p = .271$, and ANOVA $F(1, 74) = 1.07; p = .304$. Therefore, the null hypothesis was not rejected.

CHAPTER FIVE

DISCUSSION

The purpose of this study was to determine the effect of direct instruction in critical thinking on students' critical thinking and academic achievement in repeat courses. Research suggests that post-secondary students are entering institutions lacking adequate critical thinking skills to meet the demands of universities and the workforce awaiting them upon graduation. Freshmen are particularly at risk at the post-secondary level, but research suggests that students at all levels show under-developed critical thinking skills.

The United States Department of Education has published reports regarding the necessity of higher education to improve the critical thinking skills of their students. However, there has been significant debate on how best to teach critical thinking. This may be one of the main reasons that not much has been done to address this necessity.

Tutoring has been shown by research to be a support service that is crucial to student success at the post-secondary level. However, tutoring alone may be insufficient because students continue to fail courses and graduate without the level of critical thinking skills expected of those completing an undergraduate education.

Instruction in critical thinking has been shown to improve the critical thinking skills of students, but this has generally been accomplished in a discipline or course specific fashion. However, research has demonstrated that

students can be taught critical thinking outside a specific discipline. Further, students can transfer skills in critical thinking across disciplines.

For this study, students who were repeating courses were randomly assigned to experimental groups and given direct instruction in either the Thinker's Guides or Rationale programs to improve their critical thinking skills and academic achievement determined by their final grades. The Control group engaged in independent study in critical thinking. All groups received tutoring in the repeated course.

Hypotheses

Hypothesis One

For part one of this hypothesis, results revealed no significant effect of intervention group on subjects' critical thinking skills as measured by the CCTST – Form 2000. Data were analyzed using a MANCOVA that failed to show a significant effect of group on subjects' critical thinking skills.

For part two of this hypothesis, results revealed that intervention group demonstrated a significant effect on subjects' final grades. Data were analyzed using a MANCOVA that showed a significance of $p = .001$. Post hoc tests using Tukey HSD revealed the significant differences in final grade occurred between groups 1(Thinker's Guides) and Group 3 (Control). Power analysis and effect size were also analyzed. Wilk's Lambda revealed a power of .94, but a small effect size of .18. This suggests that the sample size may not have been adequate.

Hypothesis Two

For the first part of this hypothesis, data were analyzed with a Multiple Linear Regression to determine the relationship between the CAT:CV error score and subjects' final grades. Results revealed a significant relationship that explained 36.6% of the variability. Further inspection of Beta weights revealed that Beta = $-.425$ suggesting that the CAT:CV error score made a greater contribution to final grade than the CCTST -2000 Post-test Total Ranked Score.

For the second part of this hypothesis, results revealed that the CCTST-2000 Post-test Total Ranked Score demonstrated a significant relationship with subjects' final grades. However, the significance of the CCTST-2000 Post-test Total Ranked Score (Beta = $.267$) was not as great as the contribution of the CAT:CV error score (Beta = $-.425$).

Hypothesis Three

The hypothesis that intervention group would significantly affect subjects CCTST-2000 Post-test Subscale Scores was not supported by this study. A MANOVA was conducted to examine the effect of intervention group on the change in students' CCTST-2000 Post-test Subscale Scores. Results did not reveal a significant effect of intervention group on subscale scores, $p > .05$.

Hypothesis Four

Sex has been shown in prior research to contribute to students' CCTST-2000 Post-test Total Ranked Score. Male students at the post-secondary level have demonstrated higher post-test scores than females following critical thinking skills' instruction (Facione, 1990). However, the results of this study did not

support that finding. Further, sex was not a factor in students CCTST-2000 Post-test Subscale Scores or in final grade based on the results of ANCOVA, MANCOVA, and ANOVA respectively.

A Block_set ANOVA was conducted to determine the effect of the block experimental design for this study. This analysis was conducted to determine the equality of subjects at the start of this study. Results revealed a significant $F(30, 46) = 2.28$; $p = .006$ and an observed power and effect size of .99 and .59 respectively. This suggests that students were not equal at the start of this study, which may have been a factor in the results.

Implications

The purpose of this study was to determine the effect of direct instruction on students' critical thinking skills and academic achievement for students repeating courses using two programs developed to improve critical thinking skills. Neither the Thinker's Guides nor the Rationale Argument Mapping Program significantly improved the critical thinking skills of subjects in this study. Improvement in final grade was achieved by Groups 1 (Thinker's Guides) and the Control Group. The length of this study was just 13 weeks, which is about the normal length of a college semester. This may not have been a sufficient amount of time to intervene with Freshmen.

The improvement in final grade may be more of a reflection of students repeating the same class than the impact of the intervention method on their performance. In addition, all students received tutoring throughout this study, which may have significantly enhanced student achievement due to the presence

of general critical thinking associated with particular disciplines. Students repeating courses may have been on academic probation at the time of this study that may have provided enhanced motivation for them to improve their grade performance through studying and tutoring. Students who are on academic probation for two consecutive semesters are subject to academic dismissal at most universities. This may have provided an additional incentive for them to improve their academic achievement. The first semester for Freshmen can be stressful and present significant transition issues. Freshmen who come to post-secondary institutions with academic deficiencies may also be at risk.

The Category Test is routinely used as a part of the Halstead-Reitan Neuropsychological Test Battery during the assessment of individuals suspected of having brain damage. However, there is limited research on the use of the test with normal individuals. The CAT:CV is routinely used in the Office of Learning Services to aid in screening and referrals for students suspected of having learning disabilities. For this study, results suggest that the CAT:CV error score may be a tool to screen students who are exhibiting academic failure. If students are identified early in their academic careers using by CAT:CV error score, it may offer early opportunities for intervention and thus avoid repeated failure and loss of major. Ultimately, retention of these students could be increased by using the CAT:CV as a proactive screening tool.

Limitations

Sample size, assignment, instruments, measurement, and external validity were limitations for this study.

Sample Size

There has been inconsistency in the number of subjects used in previous research to evaluate the critical thinking skills of students following interventions to improve them. This may be due to the venues in which studying populations occur such as in specific college courses. Sample size was reduced from the original number of 98 who completed this study to avoid variability in critical thinking skills due to class level.

Assignment

Although efforts were taken to randomly assign students to treatment groups, the random assignment was unsuccessful. Demographic information collected on the students revealed inequality across groups, particularly in the number of courses students repeated, amount of tutoring, previous knowledge and instruction in critical thinking, study time, and work hours.

Instruments

The CCTST is the most widely used measurement of critical thinking skills because it is closely related to the cognitive skills determined by the Delphi Panel as core components of critical thinking. There is no one test that evaluates all aspects of critical thinking and the CCTST is no exception. Further, there is a test that was not used in this study that is a companion of the CCTST that evaluates the dispositions of students to think critically. This test may have provided crucial information to enhance interventions for students.

Measurement

The eligibility criteria used for this study may have further negatively impacted results by excluding students who scored between 0 and 25 errors on the CAT:CV. In retrospect, this may have been a crucial error because students with very normal performance on the CAT:CV did indeed fail courses. Including those students may have been a benefit to them and this study. The CAT:CV demonstrated a significant relationship with students' final grade, but it is not specifically designed to evaluate critical thinking even though well developed abstract reasoning and problem solving skills are necessary components for good critical thinking.

Internal Validity

The length of this study may have been a threat to internal validity for this study. Thirteen weeks for this study may not have been sufficient time for students who were from a population that included special admission students whose educational opportunities prior to entering the university may have been limited. Similar research studies have been completed during one semester, but others have spanned entire academic years or the entire undergraduate education of students.

There were additional threats to internal validity for this study. For students who demonstrated significant gains in critical thinking, these gains may have been a result of the critical thinking skills they already possessed. Analysis of the Block design used in this study revealed that students were not equal in critical thinking at the start of this study. This may suggest little impact of this

study on their actual critical thinking skills. Students were also receiving ongoing content course tutoring at the same time they engaged in critical thinking instruction in this study. Many of the tutors at this university have been trained in critical thinking skills in order to better serve the student population. Students may have received similar intervention techniques from their tutors that also improved their critical thinking skills. This may be particularly the case for students in the Control Group who had access to the materials for this study and tutoring. The Control Group may not have been a true Control Group because of their access to instructional materials and tutoring that was provided to all groups. Therefore, the effect for all groups may have been the effect of critical thinking instruction and tutoring on critical thinking skills and academic achievement. Treatment fidelity may have been a threat to internal validity as well. One graduate assistant was dedicated to providing the Thinker's Guides program and one graduate assistant for the Rationale program. While there was consistently each week by having the same graduate assistant provide the treatment intervention, there was no guarantee about the fidelity of the implementation of the treatment interventions according to their original designs. This may partially explain the lack of significant improvement in students' critical thinking skills.

Pre-testing and post-testing could have been problematic for students who were alerted to expectations for their performance. There were no guarantees about the level of incidental skills acquired by students in this study that could have made a difference in post-testing.

External Validity

The sample for this study was taken from a specific population of students who were repeating courses. The motivation for these students to volunteer for this study could have been from several factors, including pressure from departments that may drop them from repeat courses and potentially their major, special admission programs insisting they improve their performance, family, etc. Generalizing the results to the entire student population may not be possible nor to students outside this study location because of the policies regarding repeat courses. Further, results may not be generalizable to students at other institutions unless those share similar characteristics with the student population used in this study.

Novelty may also be a reason that students demonstrated higher achievement in this study. This study may have provided a difference in their general learning style. Therefore students may have improved simply because the style of this study was different from their own.

The CCTST – 2000 was used as a pre-test and a post-test measure. Although Insight Assessment (2002) reports that 13 weeks is more than enough time to use the same form for pre-testing and post-testing, students may have demonstrated less interest in successfully completing the post-test if they saw it as a familiar test. Student learning based on the pre-test may have affected their post-test performance. Pre-tests and post-tests are also threats because of their effect on statistical regression that can result in extreme scores that improve or move closer to the mean.

Summary

This study examined the effect of direct instruction in critical thinking skills on students' critical thinking and academic achievement. Intervention programs using the Thinker's Guides based on Richard Paul's model of critical thinking and Tim van Gelder's Rational Argument Mapping Program revealed no significant improvement in students' critical thinking skills. However, the Thinker's Guides did show improvement in students' final grades but students using all materials as an independent study (Control Group) in critical thinking improved grades as well. It appears that instruction in critical thinking, whether through direct instruction or independent study in addition to tutoring may be factors that contribute to the improvement of students' academic achievement. However, due to the sample and small effect size, these conclusions must be interpreted cautiously. Repeating this study with a substantial increase in sample size may be one method to determine the true effect of direct instruction on students' critical thinking and academic achievement.

The CAT:CV also revealed a significant relationship with students final grades. Although there has been very little research regarding the ability of the CAT:CV to predict students' final grades, it demonstrated a relationship to final grades in this study. There were several students with high error scores on the CAT:CV and one with an extreme error score of 130. These students may have had minimal benefit from critical thinking skills instruction or tutoring because of actual neurological impairment indicated by their very high error scores.

A final thought regarding the lack of significant improvement in critical thinking skills may be the relationship of the instruction of critical thinking skills to training in study strategies because of the meta-cognitive component inherent in both instructional interventions. One must question whether or not study strategies actually transfer to one's growth in critical thinking as reflected in students' final grades. Perhaps one of the reasons that significant improvement in final grade was observed for students exposed to critical thinking training but no concomitant increase in critical thinking as measured by the CCTST-2000 would be that specific study strategies were transferred (amenable to the dependent variable), while overall critical thinking and metacognitive skills did not improve.

Suggestions for Future Research

This study was conducted at an institution that may benefit from similar research for students who are repeating courses. The institution may benefit from assigning students to a course designed to improve their performance through instruction in critical thinking. This should be a priority for Freshmen who are failing courses at the start of their post-secondary education. However, students at all levels from Freshmen to Seniors continue to fail courses each semester. Institutions may want to require a course in critical thinking when students are repeating courses for the second time. This will give them an opportunity to improve critical thinking prior to being dropped from repeat courses and/or departments for failure to meet the requirements of their major.

The length of future studies could be extended from one semester to a full academic year. This may offer adequate time for students to be evaluated on their knowledge of critical thinking through the study rather than merely through pre-testing and post-testing.

Demographic information gathered for the subjects in this study revealed inequality across groups, particularly among the Thinker's Guides Group 1 and the Control Group 3, suggesting that the random assignment used in this study was ineffective. A suggestion for future studies of this nature would be to run an analysis of differences across demographics and re-run the MANCOVA with these differences in mind.

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Appendices

Appendix A

Millersville University 2006-2007 Repeat Course Letters

Date Field

Name Field

Street Address Field

Street line 2 Field

City, State, Zip Field

Dear First Name Field,

You are currently repeating _____ for the **first time**. According to the **recently revised Undergraduate Academic Policy**, a student, in consultation with their adviser, may repeat a course to improve the GPA, to meet minimum competency requirements, or to satisfy graduation requirements. Once the course is repeated, the new grade, credits, and grade point value replace those earned previously in the cumulative GPA. The earlier grade remains on the student's record even though it is no longer included in the computation of credits or cumulative GPA.

An undergraduate student may not take an undergraduate course of record more than three times. A course of record is defined as a course in which a student receives a grade of A, B, C, D, (including + and -) F, U, Z or W. **The academic department offering a course may drop a student from a course if the student attempts to take a course more than three times.**

I encourage you to contact the Office of Learning Services to find out about support services to help you be academically successful in this class. The Office of Learning Services is located in Room 348 on the third floor of Lyle Hall. The phone number is 717-872-3178 and the email address is learning.services@millersville.edu.

I also encourage you to keep in close contact with your academic adviser whose name is mentioned at the bottom of this letter. Wishing you a very successful semester!

Sincerely,

Dr. Michelle M. White
Director of Academic Advisement

CC: Adviser-First & Last Name Field

Date Field

Name Field

Street Address Field

Street line 2 Field

City, State, Zip Field

Dear First Name Field,

You are currently repeating _____ for the **second time**. According to the **recently revised Undergraduate Academic Policy**, a student, in consultation with their adviser, may repeat a course to improve the GPA, to meet minimum competency requirements, or to satisfy graduation requirements. Once the course is repeated, the new grade, credits, and grade point value replace those earned previously in the cumulative GPA. The earlier grade remains on the student's record even though it is no longer included in the computation of credits or cumulative GPA.

An undergraduate student may not take an undergraduate course of record more than three times. A course of record is defined as a course in which a student receives a grade of A, B, C, D, (including + and -) F, U, Z or W. **The academic department offering a course may drop a student from a course if the student attempts to take a course more than three times.**

I encourage you to contact the Office of Learning Services to find out about support services to help you be academically successful in this class. The Office of Learning Services is located in Room 348 on the third floor of Lyle Hall. The phone number is 717-872-3178 and the email address is learning.services@millersville.edu.

I also encourage you to keep in close contact with your academic adviser whose name is mentioned at the bottom of this letter. Wishing you a very successful semester!

Sincerely,

Dr. Michelle M. White
Director of Academic Advisement

CC: Adviser-First & Last Name Field

Date Field

Name Field

Street Address Field

Street line 2 Field

City, State, Zip Field

Dear First Name Field,

You are currently repeating _____ for the **third time or more**. According to the **recently revised Undergraduate Academic Policy**, a student, in consultation with their adviser, may repeat a course to improve the GPA, to meet minimum competency requirements, or to satisfy graduation requirements. Once the course is repeated, the new grade, credits, and grade point value replace those earned previously in the cumulative GPA. The earlier grade remains on the student's record even though it is no longer included in the computation of credits or cumulative GPA.

An undergraduate student may not take an undergraduate course of record more than three times. A course of record is defined as a course in which a student receives a grade of A, B, C, D, (including + and -) F, U, Z or W. **The academic department offering a course may drop a student from a course if the student attempts to take a course more than three times.**

I encourage you to contact the Office of Learning Services to find out about support services to help you be academically successful in this class. The Office of Learning Services is located in Room 348 on the third floor of Lyle Hall. The phone number is 717-872-3178 and the email address is learning.services@millersville.edu.

I also encourage you to keep in close contact with your academic adviser whose name is mentioned at the bottom of this letter. Wishing you a very successful semester!

Sincerely,

Dr. Michelle M. White
Director of Academic Advisement

CC: Adviser-First & Last Name Field

Appendix B

Millersville University Repeat Course Policy

Section 3: Undergraduate Academic Policies

Course Policies: Course Repeats

A student, in consultation with the adviser, may repeat a course to improve the GPA, to meet minimum competency requirements, or to satisfy graduation requirements. Students only need to repeat a failed course if it is specifically required for graduation. Students may repeat courses for which they have received a grade of C+, C, C-, D+, D, D-, F, W, Z, or U.

Courses failed at Millersville must be repeated at Millersville in order to earn course credit and credit toward graduation. Students may not transfer credit for any course taken at another institution that is the equivalent of a course previously taken at Millersville; this policy applies whether the course was passed or failed at Millersville University. Students may repeat courses at Millersville for which they have received transferred credit, but they will forfeit the transfer credit.

Once the course is repeated, the new grade, credits, and grade point value replace those earned previously in the cumulative GPA. The earlier grade remains on the student's record even though it is no longer included in the computation of credits or cumulative GPA. In consultation with the adviser, students who find it necessary to repeat a course will be informed of and expected to use support services available to them through the Office of Learning Services.

An undergraduate student may not take an undergraduate course of record more than three times. A course of record is defined as a course in which a student receives a grade of A, B, C, D, (including + and -) F, U, Z or W. The academic department offering a course may drop a student from a course if the student attempts to take a course more than three times.

(Approved: FS 1/20/04; AA 3/4/04)

Appendix C

Research Study Flyer

RESEARCH VOLUNTEERS WANTED!

THE TUTORING CENTER

located at 118 Lyle Hall
will conduct research on critical thinking skills and
academic achievement.

If you have repeated a course at least once, you may be
eligible to participate!

Students will be screened for critical thinking skills and,
if chosen to participate, will receive direct instruction in
critical thinking to see if both their academic
achievement and critical thinking skills improve.

If interested, please contact

THE TUTORING CENTER

Millersville University

118 Lyle Hall

717/871-2420 or TutoringCenter@millersville.edu



Appendix D

Consent Forms

INFORMED CONSENT FORM

Improved Critical Thinking Skills as a Result of Direct Instruction and Their Relationship to Academic Achievement

You are invited to participate in this research study. The following information is provided in order to help you make an informed decision whether or not to participate. If you have any questions, please do not hesitate to ask. You are eligible to participate because you have repeated a course one or more times.

This research will be conducted by Sherlynn Bessick, who is a doctoral student at Indiana University of Pennsylvania and Director of the Office of Learning Services and Tutoring Center at Millersville University. Indiana University of Pennsylvania will be the responsible institution for this research study. Research will be conducted in the Tutoring Center at 118 Lyle Hall.

The purpose of this study is to compare students' critical thinking skills to their academic achievement. Specifically, this study will research the effect of direct instruction in critical thinking on these skills as well as academic achievement. Participation in this study will require you to complete a 10 minute demographic survey, a 45 minute pre- and post- test as well as an hour each week throughout the semester for instruction. These instructional sessions are not considered a part of the normal tutoring you receive in your courses.

Initially, you will be screened with a computerized instrument, the Halstead-Reitan Computer Category Test, to determine your level of critical thinking and abstract reasoning. This process should take about 15 minutes. Based on your performance, you may be offered further participation in this study, which will begin with a 34 question multiple choice pre-test of critical thinking. You will be randomly assigned to one of two groups for direct instruction in critical thinking or asked to continue with content course tutoring and independent study in critical thinking. Instruction groups will meet for one hour each week. All members of each group will continue to receive 3 hours of tutoring each week. Following your last session, you will be given a post- test of critical thinking that will take approximately 45 minutes. Any change in your critical thinking skills as well as your end of semester grade will be compared. If you are found ineligible for this study, you may attend critical thinking workshops offered by the Tutoring Center.

There are no known risks or discomforts associated with this research. However, there are many potential benefits such as improved critical thinking skills that may help you improve your academic performance.

Your participation in this study is voluntary and you will receive no payment for your participation. You are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators or Millersville University. Your decision will not result in any loss of benefits to which you are otherwise entitled. If you choose to participate, you may withdraw at any time by notifying the Project Director or informing the person administering the tests and/or instruction. Upon your request to withdraw, all information pertaining to you will be destroyed. If you choose to participate, all information will be held in strict confidence and will have no bearing on your academic standing or services you receive from the University. Your response will be considered only in combination with those from other participants. The information obtained in the study may be published in scientific journals or presented at scientific meetings, but your identity will be kept strictly confidential. You may obtain additional information about this study from the Project Director.

If you are willing to participate in this study, please sign the statement below and return to the Tutoring Center at 118 Lyle Hall. The unsigned copy is for your records. If you choose not to participate, return the unsigned copies to the Tutoring Center.

Project Director: Sherlynn Bessick: 717/871-2031
Chair & Student Advisor: Dr. Mary Ann Rafoth.
Telephone: 724/357- 2480
Indiana University of Pennsylvania
104 Stouffer Hall
Indiana, Pennsylvania 15705

This project has been approved by the Indiana University of Pennsylvania Institutional Review Board for the Protection of Human Subjects (724/357-7730)

VOLUNTARY CONSENT FORM:

I have read and understand the information on the form and I consent to volunteer to be a subject in this study. I understand that my responses are completely confidential and that I have the right to withdraw at any time. I have received an unsigned copy of the Informed Consent Form to keep in my possession.

Name:

_____ PLEASE PRINT

Signature:

Date: _____

Phone number where you can be reached:

Best days and times to reach you:

I certify that I have explained to the above individual the nature and purpose, potential risks, and benefits associated with participating in this research study, have answered any questions that have been raised, and have witnessed the above signature.

Date: _____ **Investigator's Signature:** _____

P.O. Box 1002
Millersville, PA 17551
www.millersville.edu

MILLERSVILLE
UNIVERSITY

Office of Learning Services
Tele: 717-872-3178 FAX: 717-871-2129
e-mail: learning.servies@millersville.edu

Find Your Future Here

PERMISSION FOR SCREENING

Halstead-Reitan Computer Category Test

Improved Critical Thinking Skills as a Result of Direct Instruction and Their Relationship to Academic Achievement

The following information is provided in order to help you make an informed decision whether or not to participate in this study. If you have any questions, please do not hesitate to ask. You are eligible for this study and screening because you have repeated a course one or more times.

The Halstead-Reitan Computer Category Test is a neuropsychological instrument that measures one's conceptualization ability, higher order thinking, and abstract reasoning. It is a simple 30 minute test that reveals a great deal about how you approach and solve problems. The results will be used to determine your eligibility to participate in critical thinking skills interventions. Your scores will be released to Sherlynn Bessick, principal investigator and the Director of the Office of Learning Services and the Tutoring Center. Your scores will be anonymously reported to Ms. Bessick and used in this study. Your scores may also be anonymously reported in scientific journals or presented at scientific meetings. You will be given a copy of your results.

Please complete the following:

I _____ give my permission to be screened
(Please Print Full Name)

with the Halstead-Reitan Computer Category Test. I understand that results will be used to help me determine if there are barriers to my learning. I understand that my results will be kept in a confidential file and that I will also be given a copy of my results.

(Signature) (Date)

(Witness - Signature) (Date)

I _____ do not give my permission
to be
(Please Print Full Name)

screened with the Halstead-Reitan Computer Category Test. I understand that I may still seek services through the Office of Learning Services without being screened with this test.

(Signature) (Date)

(Witness - Signature) (Date)

Appendix E

Student Demographic Survey

Improved Critical Thinking as a Result of Direct Instruction and Their Relationship to Academic Achievement

The following information is being gathered for statistical purposes only. Please answer each question on the scantron form provided. Please provide your university ID # (example: M00....).

Please enter your MU ID#: M_____

1. Gender

- a. Male
- b. Female

2. Race

- a. African-American
- b. American Indian/Alaskan Native
- c. Asian or Pacific Islander
- d. Hispanic
- e. White – Non-Hispanic

3. Current Age

- a. 17-19
- b. 20-22
- c. 23-25
- d. 26-30
- e. Over 30

4. Current year in college

- a. Freshman
- b. Sophomore
- c. Junior
- d. Senior

5. In what discipline is your major?

- a. Humanities
- b. Sciences (including nursing, computer science)
- c. Social Sciences (including psychology)
- d. Mathematics
- e. Education

6. Have you repeated courses in your major?
 - a. Yes
 - b. No

7. Have you repeated courses categorized as general education requirements?
 - a. Yes
 - b. No

8. How many times have you repeated the same course in your major?
 - a. 0
 - b. 1
 - c. 2
 - d. 3
 - e. 4 or more

9. How many times have you repeated the same course categorized as a general education requirement?
 - a. 0
 - b. 1
 - c. 2
 - d. 3
 - e. 4 or more

10. Do you meet with your advisor each semester before registering for classes?
 - a. Yes
 - b. No

11. Have you received tutoring in courses you are repeating?
 - a. Yes
 - b. No

12. If so, how many hours per week did you attend tutoring sessions?
 - a. 1 hour
 - b. 2 hours
 - c. 3 hours
 - d. More than 3 hours
 - e. Not Applicable

13. How would you classify yourself?
- Undecided (Exploratory) Student
 - Student with a declared major
14. Have you changed your major due to an inability to meet department and major requirements?
- Yes
 - No
15. If so, have you changed your major due to repeating courses required for your major?
- Yes
 - No
 - Not Applicable
16. Have you incurred financial hardships due to repeating courses?
- Yes
 - No
17. Will your graduation be delayed due to repeating courses?
- Yes
 - No
18. Have you ever sought professor assistance in courses you have repeated?
- Yes
 - No
19. Rate your current knowledge of critical thinking.
- None
 - Limited
 - Average
 - Above Average
 - Advanced
20. Have you been taught to think critically?
- Yes
 - No

21. How many hours each week do you study for each course?
- 1 hour
 - 2 hours
 - 3 hours
 - More than 3 hours
22. How many hours each week do you study for courses you are repeating?
- 1 hour
 - 2 hours
 - 3 hours
 - More than 3 hours
 - None
23. How would you classify your registration status?
- Full-time (12 credits or higher)
 - Part-time (11 credits or less)
24. How would you classify your employment status?
- Not employed
 - Work study on campus
 - Part-time off campus
 - Full-time off campus
25. How many hours each week do you work?
- Less than 10 hours a week
 - 10 to 15 hours a week
 - 16 to 20 hours a week
 - 21 to 25 hours a week
 - Greater than 25 hours a week
 - Not employed
26. Do you repeat courses despite tutoring in those courses?
- Yes
 - No
27. Do you feel you had sufficient high school preparation for your major?
- Yes
 - No

Appendix F

Thinker's Guides Activities

Examples of Irrational Thinking

(<http://www.nizkor.org/features/fallacies/>)

Bill and Jane are arguing about the morality of abortion:

Bill: "I believe that abortion is morally acceptable. After all, a woman should have a right to her own body."

Jane: "I disagree completely. Dr. Johan Skarn says that abortion is always morally wrong, regardless of the situation. He has to be right, after all, he is a respected expert in his field."

Bill: "I've never heard of Dr. Skarn. Who is he?"

Jane: "He's the guy that won the Nobel Prize in physics for his work on cold fusion."

Bill: "I see. Does he have any expertise in morality or ethics?"

Jane: "I don't know. But he's a world famous expert, so I believe him."

Bill: "I believe that abortion is morally wrong."

Dave: "Of course you would say that, you're a priest."

Bill: "What about the arguments I gave to support my position?"

Dave: "Those don't count. Like I said, you're a priest, so you have to say that abortion is wrong. Further, you are just a lackey to the Pope, so I can't believe what you say."

Bill: "Smoking is very unhealthy and leads to all sorts of problems. So take my advice and never start."

Jill: "Well, I certainly don't want to get cancer."

Bill: "I'm going to get a smoke. Want to join me Dave?"

Jill: "Well, I guess smoking can't be that bad. After all, Bill smokes."

Peter: "Based on the arguments I have presented, it is evident that it is morally wrong to use animals for food or clothing."

Bill: "But you are wearing a leather jacket and you have a roast beef sandwich in your hand! How can you say that using animals for food and clothing is wrong!"

"Yeah, I know some people say that cheating on tests is wrong. But we all know that everyone does it, so it's okay."

"Sure, some people buy into that equality crap. However, we know that everyone pays women less than men. It's okay, too. Since everyone does it, it can't really be wrong."

The new PowerTangerine computer gives you the power you need. If you buy one, people will envy your power. They will look up to you and wish they were just like you. You will know the true joy of power. TangerinePower.

"You know, Professor Smith, I really need to get an A in this class. I'd like to stop by during your office hours later to discuss my grade. I'll be in your building anyways, visiting my father. He's your dean, by the way. I'll see you later."

"My fellow Americans...there has been some talk that the government is overstepping its bounds by allowing police to enter peoples' homes without the warrants traditionally required by the Constitution. However, these are dangerous times and dangerous times require appropriate actions. I have in my office thousands of letters from people who let me know, in no uncertain terms, that they heartily endorse the war against crime in these United States. Because of this overwhelming approval, it is evident that the police are doing the right thing."

Large scale polls were taken in Florida, California, and Maine and it was found that an average of 55% of those polled spent at least fourteen days a year near the ocean. So, it can be safely concluded that 55% of all Americans spend at least fourteen days near the ocean each year.

It is claimed by some people that severe illness is caused by depression and anger. After all, people who are severely ill are very often depressed and angry. Thus, it follows that the cause of severe illness actually is the depression and anger. So, a good and cheerful attitude is key to staying healthy.

Bill sets out several plates with bread on them. After a couple days, he notices that the bread has mold growing all over it. Bill concludes that the mold was produced by the bread going bad. When Bill tells his mother about his experiment, she tells him that the mold was the cause of the bread going bad and that he better clean up the mess if he wants to get his allowance this week.

"Men receive more higher education than women. Therefore Dr. Jane Smart has less higher education than Mr. Bill Buffoon. "

"Minorities get paid less than 'whites' in America. Therefore, the black CEO of a multi-billion dollar company gets paid less than the white janitor who cleans his office."

Smith, who is from England, decides to attend graduate school at Ohio State University. He has never been to the US before. The day after he arrives, he is walking back from an orientation session and sees two white (albino) squirrels chasing each other around a tree. In his next letter home, he tells his family that American squirrels are white.

Sam is riding her bike in her home town in Maine, minding her own business. A station wagon comes up behind her and the driver starts beeping his horn and then tries to force her off the road. As he goes by, the driver yells "get on the sidewalk where you belong!" Sam sees that the car has Ohio plates and concludes that all Ohio drivers are jerks.

Analyzing Generalizations

Use what you have just learned about fallacies to point out why each of the following examples of generalizations does not have a strong argument:

“Yesterday I met the most remarkable person. He/she is kind, considerate, sensitive, and thoughtful.”

“Well aren’t you going to stand up for our country? I thought you were a patriot?”

“Why do you always have to be so critical? Can’t you just be human for once?”

“No, I’m not a rational person. I have FEELINGS!”

“Let’s face it. The answer is LOVE. That’s the only way to create a better world.”

“Hunger is the result of overpopulation, if people had fewer children they would not be hungry.”

Choosing a College Major: How to Chart Your Ideal Path

by *Randall S. Hansen, Ph.D.*

(http://www.quintcareers.com/choosing_major.htmlhttp://www.quintcareers.com/choosing_major.html)

The most important piece of advice in this article follows this sentence, so please make note of it and repeat it to yourself as often as you need as you read this article and make decisions regarding choosing a major in college. Are you ready for it? The advice: **Don't panic.**

I know it's easier said than done, but I can't tell you how many students I have advised since the time that I have been a professor that seem in a state of panic if they are uncertain of their major, let alone a career. Choosing a major, thinking about a career, getting an education — these are the things college is all about. Yes, there are some students who arrive on campus and know exactly their major and career ambitions, but the majority of students do not, thus there is no need to rush into a decision about your major as soon as you step on campus.

And guess what? A majority of students in all colleges and universities change their major at least once in their college careers; and many change their major several times over the course of their college career.

This article is all about giving you some pointers and direction -- some steps for you to take -- in your journey toward discovering that ideal career path for you. But it is a journey, so make sure you spend some time thinking about it before making a decision. And don't be discouraged if you still don't have a major the first time you take this journey...your goal should be narrowing your focus from all possible majors to a few areas that you can then explore in greater depth. [Editor's Note: See also the [What Can I Do With a Major In...?](#) section of Quintessential Careers.]

Please also keep in mind that many schools have double majors, some triple majors, and most minors as well as majors. Way back when I was an undergraduate at Syracuse University, I was a dual major in marketing and magazine journalism. Today I am a college professor and Webmaster of a top career resources Website...which brings me to the last piece of general advice before you begin your journey: your major in college is important for your first job after graduation, but studies show that most people will change careers -- yes, careers -- about four or five times over the course of their lives — and no major exists that can prepare you for that!

The **first** stop on your journey should be an examination or self-assessment of your interests. What types of things excite you? What types of jobs or careers appeal to you? If you are not sure, start the process at [Quintessential Careers: Career Assessment](#). Also, many, if not all, college career centers have a variety of self-tests you can take to help you answer some of these questions.

The **second** stop on your journey is an examination of your abilities. What are your strengths? What are your weaknesses? What kind of skills do you have? You can begin this self-examination by looking at the courses you took in high school. What were your best subjects? Is there a pattern there? What kinds of extracurricular activities did you participate in while in high school? What kinds of things did you learn from part-time or summer jobs? While you can only do part of it now, you may want to skim through our article, [Using a SWOT Analysis in Your Career Planning](#).

The **third** stop on your journey involves examining what you value in work. Examples of values include: helping society, working under pressure, group affiliation, stability, security, status,

pacing, working alone or with groups, having a positive impact on others, and many others. Again, a visit to your college's career center should help. You can also check out our [Workplace Values Assessment for Job-Seekers](#), which examines what you value in your job, your career, and your work.

The **fourth** stop on your journey is career exploration. The University of California at Berkeley offers [Career Exploration Links – Occupations](#), which allows you to explore a general list of occupations or search for a specific occupation and provides links to resources that give you lots of information about the occupation(s) you choose. There are many schools that offer similar "what can I do with a major in...?" fact sheets or Websites, but one of my favorites is at [Ashland University](#). You can also learn more about various occupations, including future trends, by searching the [Bureau of Labor Statistics' Occupational Outlook Handbook](#). You can find all these resources -- and more -- at [Quintessential Careers: Career Exploration Tools](#).

The **fifth** stop on your journey is the reality check. You need to honestly evaluate your options. Do you really value physicians and have an interest in being a doctor, but have little skills in science? Does your occupation require an advanced degree, but your future commitments preclude graduate study? Do you have a strong interest in the arts, but your family is convinced you will become a CPA like your father? There are often ways to get around some of the obstacles during the reality check, but it is still important to face these obstacles and be realistic about whether you can get around them.

The **sixth** and final stop on your journey is the task of narrowing your choices and focusing on choosing a major. Based on all your research and self-assessment of the first five stops on your journey, you should now have a better idea of the careers/majors you are not interested in pursuing as well as a handful of potential careers/majors that do interest you. What are the typical majors found at a comprehensive university? Visit [Quintessential Careers: College Majors](#) for a listing of the typical college majors.

What are some other resources for helping you get more information about a major and/or a career?

Take advantage of:

- Your **college's course catalog** -- you'll be amazed at the wealth of information you can find here...from required courses to specialized majors and tracks.
- Your **professors**, including your academic adviser -- talk with your professors, whether you have taken a class with them or not...many of them have worked in the field in which they teach and all are experts about careers and career opportunities.
- Your **classmates**, especially upperclassmen -- these are the folk who are deep into their major, perhaps already having had an internship or gone through job interviews...use them as a resource to gather more information.
- Your **college's alumni** -- unless your college was just founded, your school probably has a deep and varied group of alums, many of whom like to talk with current students...so use them as a resource to gather more information about careers.
- Your **family and friends** -- there's a wealth of information right at your fingertips. Next time you go home or call home, ask your family about majors and careers.
- Your **college's career center** -- almost always under-appreciated, these folk have such a wealth of information at their fingertips that it is a shame more students don't take advantage of them...and not just in your senior year -- start visiting in your first year because most have resources for choosing a major and a career, as well as internship and job placement information. Read more about this option by reading our article, [It's Never Too Early -- or Too Late -- to Visit Your College Career Office](#).

Appendix G

Template for Analyzing the Logic of an Article

Template for Analyzing the Logic of an Article

Take an article that you have been assigned to read for class, completing the "logic" of it using the template below. This template can be modified for analyzing the logic of a chapter in a textbook.

The Logic of "(name of the article)"

1) The main purpose of this article is _____.

(State as accurately as possible the author's purpose for writing the article.)

2) The key question that the author is addressing is _____.

(Determine the key question in the mind of the author when s/he wrote the article.)

3) The most important information in this article is _____.

(Determine the facts, experiences, data the author is using to support her/his conclusions.)

4) The main inferences/conclusions in this article are _____.

(Identify the key conclusions the author comes to and presents in the article.)

5) The key concept(s) we need to understand in this article is (are) _____.

By these concepts the author means _____.

(Determine the most important ideas you would have to understand in order to understand the author's line of reasoning.)

6) The main assumption(s) underlying the author's thinking is (are) _____.

(Determine what the author is taking for granted [that might be questioned].)

7) If we take this line of reasoning seriously, the implications are _____.

(What consequences are likely to follow if people take the author's line of reasoning seriously?)

8) If we fail to take this line of reasoning seriously, the implications are _____.

(What consequences are likely to follow if people ignore the author's reasoning?)

9) The main point(s) of view presented in this article is (are) _____.

(What is the author looking at, and how is s/he seeing it?)

Appendix H

Rationale Activity Packet

Activity #1:

Create a reasoning map with “I should skip school” as your main position. After you have created the map, use the evaluation tools to evaluate your argument.

Activity #2:

Read the following article on fuel cells and create an analysis map with the position that “fuel cells should be used in cars” as your main position. After you have created your argument, use the analysis tools to evaluate your argument.

Activity #3:

Read the article on acupuncture and allergy relief and create an analysis map. The position you take is your choice, just make sure you can argue for or against it using the information provided in the article. After you have created your map, evaluate your argument.

Activity #4:

Read the three articles on global warming and create an analysis map. The position you take is your choice, just make sure you can argue for or against it using the information provided in all of the articles. Evaluate your argument when you are finished.

Columns



Hi Bill--

Can cars actually run on hydrogen cells? Is it just a pipe dream? Is anyone working on making it a reality?

In other words, could hydrogen cars be the future when the oil runs out?

--Fuel Cell Fred

Dear Fred,

Yes, cars can run on hydrogen [fuel cells](#). Whether or not we actually ponder it, this is just the kind of question that all of us scientifically literate voters and taxpayers need to think about. So, let's get started.



Water Molecule

What are fuel cells?

Fuel cells almost always refers to gizmos with [hydrogen](#) as the *fuel* for the main chambers (or cells), the parts of the devices where the main chemical reaction takes place and the energy is produced. You know that water is H₂O. It's got two hydrogen atoms and one oxygen atom in every molecule. And it's a pretty stable molecule. I mean boil it, freeze it, vaporize it, mix it with acid in your stomach, and it stays together, chemically bonded. But, you may also know that you can knock it apart with electricity. If you run electricity through pure or nearly pure water, bubbles form of two pure gases: hydrogen and oxygen. Hydrogen shows up on the negative electrode, and oxygen forms on the positive electrode. Try it with some distilled water; just hook a couple of wires up to, say, a 9-volt battery.

You'll get the bubbles. They're a bit tough to capture, but easy to see.
(Depending on the water you have, it may work better if you add a dash of salt--the extra [ions](#)* help the electrons flow.)

Here's the thing: This electrical atom action (this electrolysis) works the other way as well. If you combine oxygen and hydrogen, you get that energy back. In a vehicle such as a space shuttle, hydrogen and oxygen are combined and burned. The huge release of chemical energy becomes the spectacular rush of hot expanding gases that force the shuttle skyward. In a fuel cell, the idea is to combine hydrogen and oxygen slowly and in such a way that we capture the released chemical energy as electricity.



[Space Shuttle Launch](#)

Could we drink from the tailpipe?

Fundamentally, fuel-cell cars and trucks are electric cars and trucks. Instead of a battery, they have fuel cells. The exhaust is nothing but water vapor--no carbon particulates, no nitrous oxides, no unburned gasoline, no oil, just pure, drinkable, cloud-and-rain-worthy water flowing out the tail pipe as an invisible gas.

Conventional batteries, such as the ones that start cars and run the windshield wipers, or the fancy batteries that run your cell phone, all use large, long molecules, with alkaline bonds, and metals like lithium, nickel, cadmium, and lead (in order of atomic numbers--the number of protons). A hydrogen fuel cell uses the smallest atom there is, a hydrogen atom (atomic number 1), and even that has its electron stripped away. Instead of moving big molecules through thick goo like most batteries, fuel cells move nothing but protons and electrons through tiny bubbles of gas. The heart of many hydrogen fuel cells is a material that facilitates this chemical transfer of protons; these materials are called proton exchange membranes (PEMs).

Because they're inherently efficient on the molecular scale, large fuel-cell vehicles have the potential to be a great deal more efficient than regular old internal-combustion engine rigs. A typical car engine might be 28 percent efficient at converting the heat of burning gas into the mechanical work that moves it along. A fuel cell is about 50 percent efficient. So, we may be able to

build vehicles that use half as much energy to get around and don't produce exhaust.

A tricky operation

Right now, fuel cells can be a bit tricky to operate. They involve precise control of pressures, voltages, and so on. Some fuel cells use exchange membranes made of a special type of plastic impregnated with platinum, a very stable metal. Hydrogen is pumped in on one side of a thin membrane of this material, oxygen on the other. Protons are exchanged, and electricity flows out from the edges. Many scientists and engineers are working on the subtle problems that these types of fuel cells present. For example, the pressures within the cells have to be just right. The surfaces where the gases meet have to be kept clean, and they can't be fragile.

Many people think that these are solvable engineering problems. We should be able to improve fuel-cell systems the same way we have developed and improved modern gasoline engines over the last century or so. Fuel-cell devices work in laboratories very well. Right now, we've gotten them to work in all kinds of special vehicles, too. I've even driven a fuel-cell bus! It has tanks of hydrogen on the roof. It gets the oxygen its cells require right out of the air, just like you and I do. For fun (and to make a point), I drank droplets of water that condensed from the exhaust.

A hydrogen re-formation

Here's what we have to figure out: If we're going to use fuel-cell cars, where do we get the hydrogen? Right now, we can get hydrogen by "re-forming" other molecules. We can take natural gas--chemical formula CH_4 --and re-form it with oxygen to make hydrogen gas, which has two hydrogen atoms per molecule (H_2) and carbon dioxide (CO_2). This is not bad, but it's not the best option, because it takes energy, and we were trying to avoid using fuels such as gas and oil in the first place. On top of that, the main idea was to avoid pumping unnecessary CO_2 into the atmosphere. So, re-forming is probably not the best long-term solution, unless we re-formed, say, diesel fuel at very high efficiency right on board the vehicle--in the trunk of the car, for example.

		2 He
8 O	9 F	10 Ne
16	17	18

[The Periodic Table of Elements](#)

There are also fuel-cell schemes that use methanol. That's alcohol chemically related to natural gas, also called methane. It has a hydroxyl group (OH) in place of one of pure methane's hydrogen atoms. These show great promise. They're compact, quiet, and clean. You may have a fuel-cell battery in your laptop soon. Soldiers may one day lug dozens of this kind of fuel cell instead of traditional batteries for their electronic gear on the battlefield. But methanol is another chemical that's a bit toxic. And so, we're back to releasing CO₂.

Speaking of releasing CO₂, NASCAR has adopted the term *fuel cell*, but they're referring to a standard-sized box of gasoline. These are just gas tanks with handles--a whole 'nother, unrelated thing. Those cars get about 5 miles to the gallon, and they don't run very well unless they use old-fashioned leaded gasoline. In a typical day of racing, NASCAR vehicles put somewhat more than 50 kilos (over 100 pounds) of lead into the air. Yikes! Just imagine, though, if NASCAR changed its rules. Suppose those cars had to run on *real* fuel cells; just think how quickly engineers and racing teams could develop this technology. They'd be innovating like crazy. Heck, just think if they changed the rules so that you had to get by on half, or a fifth, or even a tenth as much fuel. We'd see automotive progress by next season.

So, how can we make this a reality?

For hydrogen to become the fuel of the future, we probably need to make it from water, electrolyzing the water with renewable sources of electricity--sources like solar photovoltaic panels, wind turbines, and heat engines incorporated in solar collectors or geothermal heat systems. Hydrogen molecules are very small. They leak out of joints in pipes easily. Hydrogen is itself a greenhouse gas, as is the water vapor that forms in fuel-cell exhaust. But, all things considered, it may be a big part of our transportation future, if we can get the renewable electricity to make it. Stay tuned. Better yet, become a scientist and work on these technical problems. You could change the world a few quadrillion protons at a time.

Acupuncture Pins Down Allergy Relief

Tuesday , April 03, 2007

By Dr. Manny Alvarez

FOX NEWS

ADVERTISEMENT

Hippocrates, the father of Western medicine, was a firm believer in the body's ability to heal itself, saying, "the natural healing force within each of us is the greatest force in getting well."

But long before Hippocrates, the ancient Chinese were already practicing what he would later preach, through the art of acupuncture.

With seasonal allergies torturing one-third of Americans, ancient acupuncture can provide a new kind of relief. While over-the-counter medications often come with unwanted side-effects, acupuncture does not. This makes it a welcome alternative for people looking for a new way to combat allergies this season.

Acupuncture is defined as a method of preventing and treating disease, illness, injury or pain by allowing the body to heal naturally and improve the way it functions. This is done by stimulating biologically significant points on the surface of the body.

In traditional Chinese medicine, these strategic points are usually stimulated by the insertion of acupuncture needles. However, in the current Westernized version of acupuncture, they can be stimulated through non-invasive techniques such as lasers.

No matter what type of stimulation is used, there is never any introduction of chemical substances into the body.

Getting to Know Acupuncture

The traditional Chinese medicine approach to acupuncture treatment is predicated on eight principles:

- Qi (sometimes spelled "chi") - This is the energy that gives life to all living matter. In Traditional Chinese Medicine, Qi typically refers to the functions of the internal organs as well as life force or energy.
- Yin and Yang - These two opposites make up the whole. To be healthy involves balancing Yin and Yang. Illness occurs when one of the two is either too strong or too weak.
- The Five Phases of Transformation (also known as the Five Elements) - The five elements are Metal, Wood, Water, Fire and Earth. They are related to the various organs in the body and to one another in a complex manner.
- Channels – Qi flows through a system of ducts. These ducts form a network of main channels, minor capillaries and collaterals. There are 14 main interconnected channels called "meridians" through which Qi flows. Each meridian is named for the organ it is related to e.g. Heart channel.
- Points (also known as acupuncture points) – More than 400 locations on the skin connect to the 14 main meridians or channels. The stimulation of different acupuncture points can influence the activity of the corresponding meridian in a specific manner.
- Diagnosis – It is believed that the pathological changes of the internal organs are reflected on the body surface. That is why a diagnosis is made by observation of the skin, eyes, tongue, and pulse.

- Zang-Fu Theory – This explains the physiological function, pathological changes, and inter-relationships of internal organs. The five Zang organs are the Lungs, Heart, Spleen, Liver, and Kidney. The six Fu organs are the Gall Bladder, Stomach, Large Intestine, Small Intestine, Urinary Bladder and "Triple Warmer" (three areas of the body cavity).

- Chinese Syndrome – There are eight general principles that are used to differentiate among syndromes:- Yin and Yang- Exterior (Biao) and Interior (Li)- Xu (deficiency) and Shi (excess)- Cold and Heat.

Acupuncture and Allergies

How do all of these elements fit together in the treatment of seasonal allergies? Kath Bartlett, owner of the [Asheville Center for Chinese Medicine](#) in Asheville, N.C., noted that they are used in a two pronged, "root and branch" approach. Kath has an M.S. in traditional Chinese medicine from Pacific College of Oriental Medicine, San Diego campus. She is also Board Certified in Oriental Medicine by the [National Certification Commission for Acupuncture and Oriental Medicine](#).

She explained that during allergy season, when a patient comes in with a runny nose, watery eyes, and uncontrollable sneezing, the treatment emphasis is on the symptoms, or the "branch." In between allergy seasons, the patient would continue to receive treatments, but this time the emphasis is on strengthening the immune system, or the "root," also referred to as "The Righteous Qi."

Diagnosing an allergy using traditional Chinese medicine is far more individualized than it would be with Western medicine. Allergies are analyzed by the pattern of symptoms seen in the specific patient, and the treatment is designed to relieve these particular symptoms.

The diagnosis begins with the basic belief that all allergies contain an element of dampness, which is a pathological accumulation of water. At this point, Kath explained, the acupuncturist looks at the symptoms to differentiate the nature of the allergy by determining heat and cold conditions.

In a heat condition, the phlegm or expectorant is green; there is a redness or yellow coat on the tongue, and the patient has a rapid pulse. In a cold condition, the phlegm or expectorant is white or clear and the tongue has a white coating. Once this determination has been made, the acupuncturist can target the specific acupuncture points that will alleviate symptoms.

Another technique used in addition to needle insertion is what's known as "cupping." This methodology is used to help Qi circulate. "In traditional Chinese medicine, a glass cup is usually used. There are also bamboo and plastic ones. A flame is put in and out of the cup, which causes the air inside to evaporate. This creates a vacuum effect. I put the cup on the lungs to pull out the phlegm," described Kath.

Some acupuncturists also have herbal training, like Kath; and they incorporate herbs into the allergy treatment. She uses raw herbs or parts of the plants that are cut and dried and can be brewed into the strong-flavored teas that most people associated with herbal remedies. For patients who are turned off by the pungent flavors, granulated herbs can be mixed with water and drunk that way.

Is Acupuncture Effective?

How effective is traditional Chinese medicine in the treatment of seasonal allergies? In a study published in the September 2004 issue of [Allergy magazine](#), the researchers concluded that a combination of Chinese herbs and weekly acupuncture sessions showed promise as a treatment for relieving the symptoms of seasonal allergies. The authors of the study recommended that future research investigate the effectiveness of an acupuncture and herb combination in the treatment of other conditions.

The study was done with 52 participants, between ages 20 and 58. The first group received a 20-minute acupuncture treatment weekly for six weeks, with points on the Large Intestine, Gallbladder, Lung and Liver meridians stimulated. Additional points were selected based on each patient's individual symptoms. They were also given an herbal blend of schizonepeta, chrysanthemum, cassia seed, plantago seed and tribulus.

Patients in the control group were given acupuncture, but at the same non-acupuncture points, which were away from meridians. They were treated with needles smaller than those used on the traditional Chinese medicine patients. Control patients also received a non-specific herbal formula comprised of coix seed, licorice, poria, hops, oryza, barley, hawthorn fruit, and medicated leaven.

At the end of the study period, participants in both groups were rated on their level of improvement. The first group treated with traditional Chinese medicine patients demonstrated improvements in allergy symptoms in the eyes and nose, higher levels of physical activity, and an improved psychological condition compared to patients in the control group.

For seasonal allergy sufferers still suffering with traditional Western medical treatments, or weighed down by unwanted side effects like drowsiness, may find relief in acupuncture. In fact, these patients may discover what Hippocrates learned centuries ago, the body has its own incredible power to heal.

Study Predicts Century of Drought in American Southwest

Thursday, April 05, 2007

By Andrea Thompson



ADVERTISEMENT

Human-induced change in Earth's atmosphere will leave the American Southwest in perpetual drought for the next 90 years, a new study finds.

Conditions in the southwestern states and portions of northern Mexico will be similar to those seen during a severe multiyear drought in the Southwest during the 1950s, as well as the drought that turned the Great Plains into the [Dust Bowl](#) in the 1930s.

The southern United States lies in a climatic region called the subtropics, which is dry because "the atmosphere moves water out of those regions," explained study team leader Richard Seager of Columbia University's [Lamont Doherty Earth Observatory](#).

• [Click here to visit FOXNews.com's Natural Science Center.](#)

The moist air is transported to temperate regions at higher latitudes.

The study, published in the April 5 issue of the journal [Science](#), found that as greenhouse gases warm the air, it can hold more moisture, so the atmospheric flow moves more water vapor out of subtropical zones and into higher latitudes.

The dry areas then become drier, and the wet become wetter.

This flow, known as the [Hadley cell](#), features rising air over the equator and descending air over the subtropics, which suppresses precipitation.

"And that Hadley cell, in a warming world, expands poleward," Seager said, bringing the U.S. Southwest more under the influence of the descending air.

Similar changes in the atmosphere produced past droughts and conditions such as the Dust Bowl, but the study found that the ultimate cause of historic droughts was natural, unlike this projected drought.

During those droughts, La Niña, El Niño's cool-water counterpart, brought cooler ocean temperatures to the equatorial Pacific, which resulted in drier conditions over North America.

The researchers used climate models to determine the level of drought based on the amount of evaporation at the ground subtracted from the amount of precipitation that falls at the surface.

The balance between these two processes is what maintains rivers and groundwater flow. As less water is available, water resources become jeopardized.

"The lifeline there is the Colorado River," Seager said, and it and other rivers are already stressed by the 10th year of drought in the Southwest.

As populations in the Southwest increase, governments will have to make adjustments to reduce water usage, but Seager and others unsure just what those changes should be.

Global Warming Is Threat to Great Barrier Reef, Amazon Rain Forests, Mexican Deserts

Friday, April 06, 2007

Associated Press

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BRUSSELS, Belgium —

An environmental group said Thursday some of the world's greatest natural treasures are threatened with destruction because of global warming — from the Great Barrier Reef to the Amazon rain forests and the unique ecosystem of the Mexican desert.

On the sidelines of a climate change conference in Brussels, the [World Wide Fund for Nature](#) issued a list of 10 regions suffering serious damage from global warming, and where it has projects to limit further damage or help people adapt to new conditions.

"What we are talking about are the faces of the impacts of climate change," said Lara Hansen, WWF's chief scientist on climate issues.

The group said coral reefs around the world, including the [Great Barrier Reef](#) in Australia and the Meso American Reef off Belize, begin to lose their color and die with a rise in ocean waters of just 1.8 degrees Fahrenheit. They are also threatened by the increasing ferocity of tropical storms, another effect of global warming.

Environmentalists project the temperature of the Amazon River could rise by 3.6 to 5.4 degrees Fahrenheit within 50 years, turning between up to 60 percent of the rain forest into a dry savanna.

In the Bering Sea, warmer winters are leading to the earlier breakup of spring ice and driving salmon stocks closer to the North Pole, disrupting the Arctic ecosystem. Melting ice is also diluting sea water and affecting nutrients for small organisms on which fish feed.

In the Valdivian rain forest in Chile and Argentina, the Alerce tree — which can live for 3,000 years — is threatened by forest fires and declining rainfall. Melting glaciers mean groundwater in the region will also become more scarce.

The [Chihuahua Desert](#) straddling the U.S.-Mexican border is suffering from drought and intensive farming and overgrazing. North America's largest desert, the Chihuahua has 3,500 unique plant species, including an array of cactus and yucca, that could be at risk.

Many of the regions at risk were singled out in a report by the Intergovernmental Panel on Climate Change, an authoritative body of 2,500 scientists. The report, which is undergoing governmental review at the five-day conference in Brussels, projects specific consequences for each degree of rising global temperatures, which the IPCC agrees is largely caused by human activity.

Some damage at the 10 areas listed by WWF is irreversible, such as shrinking glaciers, Hansen said. Certain types of coral reefs, however, can recover.

The WWF listing also said:

— Six of seven species of Caribbean turtles are endangered as rising sea levels swamp nesting beaches and feeding grounds.

— Some Himalayan glaciers are receding by 33 to 49 feet per year, causing floods now and threatening summer drought in the future.

— Glaciers in the Tibetan plateau that feed China's Yangtze River are also shrinking, adding to water flows now but threatening shortages of water, food and electricity to 450 million people as they reach a critical point.

— The Bay of Bengal is rising and increasingly violent rainstorms in India could inundate coastal islands, destroy mangrove forests and affect India's Sunderbans, home to the largest wild population of Bengal tigers and to 1 million people.

— Scientists predict East African coastal forests and the offshore ecosystem will also be vulnerable to more frequent and intense storms that will damage agriculture, shoreline mangroves and coral reefs.

Global Climate Report: Earth Facing Major Hunger, Water Shortages, Massive Floods, Avalanches

Saturday, April 07, 2007

Associated Press

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BRUSSELS, Belgium —

The Earth faces increased hunger and water shortages in the poorest countries, massive floods and avalanches in Asia and species extinction unless nations adapt to climate change and halt its progress, according to a report approved Friday by an international conference on global warming.

Agreement came after an all-night session during which key sections were deleted from the draft and scientists angrily confronted government negotiators who they feared were watering down their findings.

"It has been a complex exercise," said Rajendra Pachauri, chairman of the [Intergovernmental Panel on Climate Change](#).

- [Click here to read the full report.](#)

Several scientists objected to the editing of the final draft by government negotiators but in the end agreed to compromises. However, some scientists vowed never to take part in the process again.

The climax of five days of negotiations was reached when the delegates removed parts of a key chart highlighting devastating effects of climate change that kick in with every rise of 1.8 degrees, and in a tussle over the level of scientific reliability attached to key statements.

There was little doubt about the science, which was based on 29,000 sets of data, much of it collected in the past five years. "For the first time we are not just arm-waving with models," Martin Parry, who conducted the grueling negotiations, told reporters.

The United States, China and Saudi Arabia raised many of the objections to the phrasing, often seeking to tone down the certainty of some of the more dire projections.

The final IPCC report is the clearest and most comprehensive scientific statement to date on the impact of global warming mainly caused by man-induced carbon dioxide pollution.

"The poorest of the poor in the world — and this includes poor people in prosperous societies — are going to be the worst hit," said Pachauri. "People who are poor are least able to adapt to climate change."

The report said up to 30 percent of the Earth's species face an increased risk of vanishing if global temperatures rise 3.6 degrees Fahrenheit above the average in the 1980s and 1990s.

Areas that now suffer a shortage of rain will become even drier, adding to the risks of hunger and disease, it said. The world will face heightened threats of flooding, severe storms and the erosion of coastlines.

"This is a glimpse into an apocalyptic future," the Greenpeace environmental group said of the final report.

Without taking action to curb [carbon emissions](#), man's livable habitat will shrink starkly, said Stanford scientist Stephen Schneider, one of the authors. "Don't be poor in a hot country, don't live in hurricane alley,

watch out about being on the coasts or in the Arctic, and it's a bad idea to be on high mountains with glaciers melting," he said.

"We can fix this," by investing a small part of the world's economic growth rate, said Schneider. "It's trillions of dollars, but it's a very trivial thing."

Negotiators pored over the 21-page draft meant to be a policy guide for governments. The summary pares down the full 1,572-page scientific assessment of the evidence of climate change so far, and the impact it will have on the Earth's most vulnerable people and ecosystems.

More than 120 nations attended the meeting. Each word was approved by consensus, and any change had to be approved by the scientists who drew up that section of the report.

Though weakened by the deletion of some elements, the final report "will send a very, very clear signal" to governments, said Yvo de Boer, the U.N.'s top climate official.

The summary will be presented to the [G-8 summit](#) of the world's richest nations in June, when the European Union is expected to renew appeals to U.S. President [George W. Bush](#) to join in international efforts to control emissions of fossil fuels.

This year's series of reports by the IPCC were the first in six years from the prestigious body of some 2,500 scientists, formed in 1988. Public awareness of climate change gave the IPCC's work unaccustomed importance and fueled the intensity of the closed-door negotiations during the five-day meeting.

"The urgency of this report prepared by the world's top scientists should be matched by an equally urgent response from governments," said Hans Verolme, director of the global climate change program of the World Wide Fund for Nature.

"Doing nothing is not an option," he said.

During the final session, the conference snagged over a sentence that said the impact of climate change already were being observed on every continent and in most oceans.

"There is very high confidence that many natural systems are being affected by regional climate changes, particularly temperature increases," said the statement on the first page of text.

But China insisted on striking the word "very," injecting a measure of doubt into what the scientists argued were indisputable observations. The report's three authors refused to go along with the change, resulting in an hours-long deadlock that was broken by a U.S. compromise to delete any reference to confidence levels.

It is the second of four reports from the IPCC this year; the first report in February laid out the scientific case for how global warming is happening. This second report explains what the effects of global warming will be.

European Environment Commissioner Stavros Dimas said the report will spur the EU's determination to curb greenhouse gas emissions.

"The world needs to act fast if we are to succeed in stabilizing climate change and thereby prevent its worst impacts," Dimas said in a statement.

For the first time, the scientists broke down their predictions into regions, and forecast that climate change will affect billions of people.

Africa will be hardest hit. By 2020, up to 250 million people are likely to be exposed to water shortages. In some countries, food production could fall by half, it said.

North America will experience more severe storms with human and economic loss, and cultural and social disruptions. It can expect more hurricanes, floods, droughts, heat waves and wildfires, it said.

Parts of Asia are threatened with massive flooding and avalanches from melting Himalayan glaciers. Europe also will see its Alpine glaciers disappear. Australia's [Great Barrier Reef](#) will lose much of its coral to bleaching from even moderate increases in sea temperatures, the report said.