THE INFLUENCE OF AN INTERDISCIPLINARY COURSE ON CRITICAL THINKING SKILLS

DISSERTATION

Presented to the Graduate Council of the

University of North Texas in Partial

Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

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Denton, Texas

August, 1999

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The effect of an interdisciplinary algebra/science course on students' critical thinking skills was examined. A traditional college algebra course was used as a comparison group. The students in the sample enrolled in college algebra and then half were randomly placed into the interdisciplinary course. A quasi-experimental pretest-posttest camparison group design was used. The Watson-Glaser Critical Thinking Appraisal was used to measure the students' critical thinking skills. This instrument consists of an overall critical thinking score as well as five subscores in the areas of Inference, Recognition of Assumptions, Deduction, Interpretation and Evaluation of Arguments.

It was found that the students in the interdisciplinary course made greater gains in the overall critical thinking score as well as in four of the five subscores. However, the differences in the gains made in the two courses were not statistically significant.

Disregarding course, other factors that were found to be closely related to critical thinking were Composite ACT, grade received in the course, Math ACT and grade point average. It was also found that students whose majors were in the Schools of Arts and Letters or Science and Technology scored higher on critical thinking than students whose majors were in the Schools of Business or Education. Factors found to have no relationship to critical thinking were ethnicity, gender and classification.

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CHAPTER I

INTRODUCTION

For centuries people have been fascinated by the way the human mind thinks. From Rene Descartes' "I think, therefore, I am" to J.B. Watson's behaviorism, from Gestalt psychology to classical conditioning, from psychometrics to artificial intelligence, endless attempts have been made to identify, classify, explain and measure different ways of thinking. One of the currently popular classifications of thinking is critical thinking.

The study of critical thinking can be traced at least as far back as Socrates who used probing questions to teach his subjects to think critically (Sonoma, 1998). The term "critical thinking" first gained widespread acceptance with the appearance of Edward Glaser's work *An Experiment in the Development of Critical Thinking* (Glaser, 1941).

Although it may not be clear what the precise definition of critical thinking is, it is apparent that most consider it something desirable in our institutions of higher education. As stated in a recent issue of *The Teaching Professor* (Weimer, 1999, p.6):

"We're all for critical thinking...endorsing it much like we do motherhood and apple pie. We think our students don't do it, and we aspire to teach them how."

Another topic that has generated much interest in recent years is inter-disciplinary studies. In the past, different subjects were often taught as though they were isolated from one another and had nothing in common. Now two or more subjects are often combined into a single interdisciplinary course. These courses examine not only the individual subjects but their interrelationships as well. Some examples that are currently being taught, or that have been taught in the past year, are listed below:

University of Toledo (Toledo, 1999)	*The Experience of Science* (Biology and physics)
University of Wisconsin (Wisconsin, 1999)	*Politics and Sports*
Northeastern University (Northeastern, 1999)	*Physical Chemistry with Biological Applications*
Ashland University (Ashland, 1999)	*Science as a Cultural Force* (For chemistry or philosophy credit)
Highpoint University (Highpoint, 1999)	*Philosophy in Literature*
Boston University (Boston, 1999)	*Psychology and Criminal Justice*

Some universities even offer degrees in Interdisciplinary Studies (e.g. Iowa State University (Iowa State, 1999) Southwest Texas State University (Southwest Texas State, 1999). George Mason University (George Mason, 1999) has a Linked Courses Program in which professors from different areas work together to coordinate assignments and readings. As with critical thinking, there is a general consensus that interdisciplinary studies within our universities is something that is desirable. In *Interdisciplinary Teaching: Why & How* (1993, p.1) Gordon Vars says that in recent years...

> "...interest in interdisciplinary teaching and curriculum
> has increased exponentially".

With all of the recent interest in critical thinking skills and interdisciplinary studies, it is natural to ask if the two somehow related. Do interdisciplinary studies somehow increase students' abilities to think critically? The primary goal of this study was to answer that question.

While many authors (see e.g., Vars, 1993; Paul, 1990) espouse the benefits of interdisciplinary teaching on critical thinking skills, few (if any) studies have been done that actually examine the relationship between the two. In this study, the critical thinking skills of students enrolled in an interdisciplinary Algebra for the Sciences course were examined. This is a course that was developed at Southeastern Oklahoma State University and was taught for the first time in the spring of 1998. The development of the course was funded by a grant from the National Science Foundation.

As Spaulding and Kleiner (1992, p.166) point out, "the factors that influence the development of critical thinking are complex" and "future research needs to effectively locate those factors which influence performance." The primary goal of this research was to see if interdisciplinary studies might be one such factor.

Problem

What effect does an interdisciplinary course have on students' critical thinking skills?

Purposes of the Study

The primary purpose of this study was to determine to what extent an interdisciplinary approach to teaching math and science improves students' critical thinking skills. A secondary purpose was to determine whether gender, age, ethnicity, major, grade point average, Math ACT Composite ACT, or grade in the course also influence students' critical thinking skills and how these factors interact in an interdisciplinary course.

Hypotheses

1. Students who take an interdisciplinary algebra course will improve their critical thinking skills significantly more than students who take a traditional college algebra course. They will also show significantly more improvement in the following specific areas of critical thinking: inference, recognition of assumptions, deduction, interpretation and evaluation of arguments.
2. There will be no significant interaction between type of course (interdisciplinary vs. traditional) and any of the other factors (gender, major, ethnicity, grade point average, grade in the course, age, Composite ACT, and Math ACT).

Significance of the Study

Incoming college students often do not think as critically as professors want or expect them to (Pascarella and Terenzini, 1991). One field where this is especially true is mathematics. To do well in mathematics, a student must not only learn how to solve certain problems, but must learn why they are solved that way. Too many mathematics students, because of their weak critical thinking skills, rely on rote memorization and "absorb concepts and facts only long enough to get through the next test" (National Research Council, 1996, p.22).

Another frequent problem in mathematics is motivation. Students are often not motivated to do well in mathematics because they do not see its relevance to what they want to do in life. Some professors teach the skills and assume the student can apply them. Others may show an application or two and assume the student can imagine other applications as well. Unfortunately, the students often cannot do this, again, because of their weak critical thinking skills.

Science is another area in which critical thinking skills are important. At least one researcher even considers the scientific process to be almost synonymous with critical thinking (Logan, 1987). In science, students must be able to develop theories or hypotheses, test those theories and reach valid and justifiable conclusions based on empirical evidence, all while recognizing what assumptions are being made and how things differ if those assumptions are not met. This fits most of the definitions of critical thinking used by other researchers. Therefore, it seems natural to conclude that students with better critical thinking skills would do better in science and, conversely, that more exposure to science would improve critical thinking skills.

In this study, an attempt was made to determine the effect (if any) that interdisciplinary courses have on students' critical thinking skills. The results could possibly be used in other courses and at other universities to improve students' critical thinking skills, especially in the areas of science and mathematics.

In this study, an attempt was also made to corroborate other researchers' findings with regards to critical thinking. For instance, Spaulding and Klein (1992) found a significant correlation between critical thinking and grade point average. Pascarella (1991) found a significant correlation between critical thinking and grade received in a freshman course.

Finally, some aspects of this study were exploratory in nature and may lead to new hypotheses regarding critical thinking skills that need to be tested in later research studies.

Definition of Terms

1. "Critical Thinking" - The ability to a) define a problem, b) select pertinent information for the solution of a problem, c) recognize stated and unstated assumptions, d) formulate and select relevant and promising hypotheses, and e) draw valid conclusions and judge the validity of inferences (Dressel and Mayhew, 1954).

This is the definition used by the Watson-Glaser Critical Thinking Appraisal (the instrument used in this study).

2. "Interdisciplinary" - Emphasizing the connections, the interrelations, among various areas of knowledge (Vars, 1993).

Limitations

The generalizability of the study may be limited to only the fields of science and mathematics. However, Spaulding and Key (1992) found that the discipline of study "did not seem to matter" when considering the effect on critical thinking skills. Therefore, an argument could be made that the results are pertinent to other disciplines as well.

Delimitations

Only one institution, Southeastern Oklahoma State University, was used in this study. Data were gathered from day classes only and therefore contained mostly traditional students. The results may not be generalizable to other institutions or nontraditional students. The four sections of the new course and the four comparison sections of the traditional algebra course were taught by only two instructors. As a result, some aspects of the study may be applicable to only these instructors.

Assumptions

1. That critical thinking is a concept that is definable, identifiable, measurable and desirable for students of higher education.

2. That the Watson-Glaser Critical Thinking Appraisal Instrument accurately and consistently measures critical thinking.

CHAPTER TWO

LITERATURE REVIEW

Defining Critical Thinking

There are almost as many definitions of critical thinking as there are critical thinkers. Consider Richard Paul in *Critical Thinking: What Every Person Needs to Survive in a Rapidly Changing World* (Paul, 1990, p.51):

> "Critical thinking is disciplined, self-directed thinking which exemplifies the perfections of thinking appropriate to a particular mode or domain of thought".

Or Ernest Pascarella and Patrick Terenzini in *How College Affects Students* (1991, p.118):

> "Critical thinking typically involves the individual's ability to do some or all of the following: identify central issues and assumptions in an argument, recognize important relationships, make correct inferences from data, deduce conclusions from information or data provided, interpret whether conclusions are warranted on the basis of the data given, and evaluate evidence or authority".

Or Stephen Brookfield in *Developing Critical Thinkers: Challenging Adults to Explore Alternative Ways of Thinking and Acting* (1987, p.13):

"Being a critical thinker involves more than cognitive activities such as logical reasoning or scrutinizing arguments for assertions unsupported by empirical evidence. Thinking critically involves our recognizing the assumptions underlying our beliefs and behaviors. It means we can give justifications for our ideas and actions".

Or Stephen Norris and Robert Ennis in *Evaluating Critical Thinking* (1989, p.1):

"Critical thinking is reasonable and reflective thinking that is focused upon deciding what to believe or do".

Or Robert Boostrom in *Developing Creative and Critical Thinking* (1993, p.198):

"When you think critically about what you hear or read, you decide first what the words mean, then whether they make sense, and finally whether you believe them. The first step in this process - deciding what the words mean - involves thinking not only about what is said in a literal, straightforward way but also about what is only hinted at. To think critically, you have to read between the lines".

Or Peter Facione in *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction* (1995, p.11):

"We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based".

Many other definitions exist such as "thinking about one's thinking" (Ivogeler, 1995), "learning to observe" (Berthoff, 1981), or "thinking with skepticism" (McPeck).

Critical Thinking in Higher Education

Regardless of how one defines critical thinking, the general consensus is that it is something desirable, especially in institutions of higher education (see, e.g., Watson and Glaser, 1980; Pascarella and Terenzini, 1978; Paul, 1990). As Pascarella (1987, p.5) has noted:

> "A major aim of higher education has been to enhance one's ability to think critically, to reason and to evaluate and weigh evidence judiciously in making decisions and choices among alternate courses of action. This cluster of intellectual skills ...has often been identified as one of the major outcomes of higher education".

Pecorino (1986, p.1) agrees, saying:

> "...all educated people, and certainly all those who are awarded degrees in higher education, ought to have such skills".

There does not seem to be a general agreement on whether our educational institutions have been successful in developing students' critical thinking skills. As far back as 1941, Glaser (1941, p.9) noted that:

> "There has been too much emphasis in our schools upon feeding

students detailed information which has little or no relevance to their needs and lives, and which in large measure they do not assimilate. Too often the procedure has been for the teacher to hand down ready-made generalizations and conclusions rather than to work with the students at problems which have significance for them, helping them to learn how to arrive at generalizations, how to test these generalizations in practice, and how to revise them in the light of new experience. In short, there has been too much concern with having pupils memorize the accepted answers, and not enough concern with guiding them in the processes and methods of arriving at well-found answers".

Weimer (1999) states that:

> "Unless students are specifically taught critical thinking skills, only a small number acquire those skills in college."

Others, such as Pascarella, believe that students do leave college with better critical thinking skills than when they arrived and that these gains can be attributed to their college experience. In summarizing five separate studies, including one of his own, Pascarella (1991 p.129) says:

> "The weight of evidence clearly supports the notion that college has a net positive influence on the development of critical thinking."

Major Studies in Critical Thinking

Some of the most significant studies in the area of critical thinking were done prior to 1967 (Pascarella, 1991). Dressel and Mayhew (1954) conducted a study of more than 1700 students from eleven institutions. They found statistically significant freshmen year gains in critical thinking. Lehman (1963) administered the ACE Test of Critical Thinking Ability to 1051 freshmen upon entrance to college and then at the end of each year until they graduated. He also found statistically significant gains in critical thinking with the greatest gain coming between the beginning and end of the freshman year.

More recently, Pascarella (1989) conducted a study using the Watson-Glaser Critical Thinking Appraisal which reports a total score and five subscores: Inference, Recognition of Assumptions, Deduction, Interpretation and Evaluation of Arguments. He found that first-year college students made statistically significant gains in the total score and the last two subscores (Interpretation and Evaluation) but not in the first three (Inference, Assumptions and Deduction). McPeck (1985) found that critical thinking performance "improves as the number of total college hours increase." Steinberg and Shapiro (1982) found that in tests of critical thinking, students with "more total college credit hours performed better."

Closely related to the idea of critical thinking is the 7-stage sequence called the reflective judgment model first postulated by Kitchener and King (1981). At stage 7 of this model, judgments are achieved through the process of critical inquiry and evaluation. Kitchener and King used Reflective Judgment Interview (RJI) scores to measure how students justify their beliefs about complex intellectual problems. Kitchener (1977) found that academic major may be a factor related to reflective judgment. Pohl and Pervin (1968) found that applied science majors scored significantly lower in cognitive complexity than liberal arts majors. Other studies have been done to detect differences in critical thinking skills among students with different majors (Spaulding and Kleiner, 1992; Keeley, Browne and Kreutzer, 1982;Welfel, 1982), but in each of these studies, no significant differences have been found.

McMillan (1987) did an extensive review of twenty-seven separate studies that focused on the critical thinking skills of college students. He agreed with the studies mentioned above that overall, college attendance enhances critical thinking. He also found, nonetheless, that "the use of specific instructional or course conditions" did not significantly enhance students' critical thinking. Some of the studies he reviewed and their findings are listed below:

Bailey(1979)	An instructional paradigm emphasizing problem solving enhanced critical thinking.
Beckman(1956)	Courses in argumentation and discussion did not improve critical thinking.

Dressel & Mayhew(1954)	Students with the lowest pretest scores showed the greatest gains in critical thinking.
	Students' critical thinking gains differed from instructor to instructor.
	Science courses emphasizing critical thinking did not enhance critical thinking.
Lyle(1958)	Psychology course emphasizing critical thinking did not enhance critical thinking.
Fishbein(1975)	Students grouped with similar students scored higher than students grouped randomly.
Hardin(1977)	No difference found between self-paced instruction and lecture approach.
Shuch(1975)	Students using paper and pencil calculations scored higher than those using calculators.
Susksringarm(1976)	Biology courses emphasizing inquiry did enhance critical thinking.
Williams(1951)	No significant differences found between debate students and control students.

Interdisciplinary Courses and Critical Thinking

Only one of the studies reviewed by McMillan studied the effect of an interdisciplinary course. Jones (1974) compared three courses: a traditional social science course, an interdisciplinary general education course taught traditionally (lecture method), and an interdisciplinary general education course taught using a values clarification method. He found that the traditional social science course had significantly lower posttest scores than the two interdisciplinary courses. However, he also found no significant differences in the pretest and posttest scores of either interdisciplinary course. The major problem with this study was that the groups being compared were not equivalent. The control group and experimental group had not been chosen randomly. Instead, they were self selected in that the students had chosen which class to enroll in.

Critical Thinking Within a Discipline

Other studies have focused on the critical thinking skills of students in particular disciplines such as nursing (Rubenfield and Scheffer, 1995), sociology (Baker, 1981), computer science (Gleichsner, 1994) or history (O'Reilly, 1983). Most of these studies compared two different teaching techniques and their results on students' critical thinking skills. In general, these studies agreed with McMillan (1987) that "particular instructional or course conditions" did not significantly enhance critical thinking.

Theoretical Framework of Reference

Since critical thinking is needed in everyday life, and life is itself interdisciplinary in nature, it seems reasonable to think that an interdisciplinary course should improve students' critical thinking skills. In the 1920's and 1930's Alfred North Whitehead, a mathematician and philosopher at Harvard University, decided to emphasize in his teaching, "the interrelatedness of, as well as the continuous interaction among, every aspect of reality" (Gill, 1993, p.15). Whitehead believed that the "division of various fields of knowledge from each other, would in the long run render people incapable of making judgments about the general" (Gill, 1993, p.212). These "judgments" are a large part of what constitutes critical thinking. Judd arrived at the conclusion that "active thinking tends in the direction of synthesis of ideas. The mind does not dwell on isolated items of experience but combines these items into integrated systems" (Glaser, 1941, p.22). A good interdisciplinary course would almost certainly involve the combining of experiences from two or more disciplines. Maier makes a distinction between learning and reasoning. He says that learning involves the "association of contiguous experiences" and that repetition is necessary for this to occur. On the other hand, he defines reasoning as "a reorganization of isolated experiences in terms of a goal" (Maier, 1934, pp.181-194). Glaser claims that "Numberless experiments have shown that ...forgetting (of information) is the rule rather than the exception in American schools. It merely shows, among other things, that the pupils have been taught wastefully, and that the curriculum is highly disjointed" (Glaser, 1941, p.45). Vars (1993) says that interdisciplinary teaching "makes it possible to stress thinking and interpersonal skills that are too often overlooked in conventional instruction" (Vars, 1993, p.64). In *Cooperative Learning: Critical Thinking and Collaboration Across the Curriculum*, Adams and Hamm state that "The research evidence suggests that giving students multiple perspectives and entry points into subject matter increases thinking and learning" (Adams and Hamm, 1996, p.38).

Conclusions from Literature Review

There are several conclusions that can be drawn from the combination of all the aforementioned studies and opinions dealing with critical thinking.

1. Faculty want their students to think critically but in most cases do not believe that they do.
2. There is no universal agreement on what constitutes "critical thinking."
3. It is not clear (partly because of the previous conclusion) to what extent university instruction improves students' critical thinking skills.
4. Within a single discipline, particular instructional and course conditions do not significantly improve critical thinking.
5. Few reliable studies have been done to determine the effect interdisciplinary courses have on students' critical thinking.

The Contributions of This Study

This study addresses conclusion #5 above. Combined with other similar studies, like some of the ones mentioned above, it also addresses conclusion #3. The results of this study can be used to determine if the benefit gained in developing an interdisciplinary course are worth the time, effort and resources involved in such an undertaking.

CHAPTER THREE

PROCEDURES FOR THE COLLECTION OF DATA

Introduction

This study was conducted at Southeastern Oklahoma State University in the spring and fall semesters of 1998. A total of eight algebra classes were used in the study - four classes of the experimental course and four classes of the traditional course. All of the classes were be taught by two instructors - Elliott and Oty. In the spring, Elliott taught the experimental course at 9:30 MWF and the traditional college algebra course at 10:30 MWF. Oty taught the traditional college algebra course at 9:30 MWF and the experimental course at 10:30 MWF. This process was repeated as closely as possible in the fall of 1998. However, in the fall Southeastern began teaching MWF classes starting on the hour rather than the half-hour so the times were changed to 10:00 and 11:00 rather than 9:30 and 10:30.

In the course schedule in the spring of 1998 there were two sections listed as College Algebra, one at 9:30 MWF and one at 10:30 MWF. Fifty students were allowed into each of these courses. On the first day of class, half of the students from each section were chosen at random (using a random number generator) to participate in the new Algebra for the Sciences course. They were not told that the course was different than the traditional college algebra course and the two instructors were careful to continue referring to the course as College Algebra. This made for a total of four sections - two sections of traditional College Algebra (the comparison group) and two sections of the new interdisciplinary course Algebra for the Sciences (experimental group). The process was repeated as closely as possible in the Fall of 1998, resulting in a total beginning sample size of 211 students (118 in the comparison group and 93 in the experimental group). Because of the high drop rate in freshman-level mathematics classes the ending sample size was only 143 (74 in the comparison group and 68 in the experimental group).

Research Design

The research design of this study was quasi-experimental with students chosen for the new course or the traditional course completely at random. A Pretest-Posttest with control group design was used to test for differences in critical thinking skill gains between those students completing the interdisciplinary algebra course and those students completing the traditional algebra course.

Procedures for Data Collection

Critical thinking data were collected using Form A of the Watson-Glaser Critical Thinking Appraisal given at the beginning of the semester (the second class period) and Form B of the Watson-Glaser Critical Thinking Appraisal given at the end of the semester (last or next to last regular class period). Demographic data (including gender, age, ethnicity, Math ACT, and grade point average) were gathered from the student's current transcript (which was accessible online to both instructors of the course).

Instrument

The instrument used for measuring critical thinking skills was the 1997 version of the Watson-Glaser Critical Thinking Appraisal (WGCTA) published by The Psychological Corporation (Watson and Glaser, 1980). The WGCTA was originally developed in 1942 by Goodwin Watson and Edward Glaser and underwent a major revision in 1980. It consists of three forms, A, B and F, each of which consists of 80 multiple choice items. Forms A and B were designed to be used in pretest-posttest situations and thus were used in this study. The WGCTA reports a total score and five subscores. The subscores are, Inference, Recognition of Assumptions, Deduction, Interpretation and Evaluation of Arguments. The test takes 40 to 50 minutes to complete.

The WGCTA Manual reports several different types of reliability measures. For internal consistency, split-half reliability coefficients were calculated and were corrected for test length using the Spearman-Brown formula. These coefficients for freshmen in four-year colleges were found to be .80 for Form A and .79 for Form B. For stability of test scores over time, the correlation was found to be .73. The correlation between the two forms of the instrument was found to be .75. Other independent researchers have estimated the reliability of the WGCTA to be between .70 and .82 (Norris and Ennis, 1989).

No measure of content validity is cited in the WGCTA manual, primarily because there is not general agreement on the definition of critical thinking. Several studies have helped establish the construct validity of the WGCTA (Sorenson, 1966; Agne and Blick, 1972; Fogg and Calia, 1967; Burns, 1974). The WGCTA is also significantly correlated with other measures of academic achievement including grade point average, course grades, the Otis-Lennon Mental Ability Test, the American College Testing Program (ACT) and the Scholastic Aptitude Test (SAT).

Norris and Ennis (1989) cite the WGCTA as the "bench mark against which others must be compared."

Population and Sample

The population was all college and university students who take a college-level algebra course. More broadly defined, an argument could be made that the population was all students who take any mathematics course that can be taught from a science-application viewpoint.

The sample consisted of those students who enrolled in an algebra course taught by Elliott or Oty in the spring and fall of 1998. An attempt was made in Chapter 4 to show that these students did not differ significantly in pertinent characteristics from the overall population.

The Comparison Group

The comparison group consisted of the students randomly assigned to the four traditional college algebra classes. A traditional college algebra text was used (Sobel and Lerner, 1995). The instructional technique used was primarily lecture with minimal discussion. The topics covered were the usual topics in a college algebra course and consisted of lines, quadratics, functions, circles, exponentials, logarithms, and linear systems of equations. At SOSU, this course is intended primarily for those students planning to take trigonometry and/or calculus in subsequent semesters. The topics were introduced entirely from a mathematical viewpoint. The only mention of any other fields besides mathematics occurred in one section on word problems and from an occasional problem in other homework assignments. The total estimated time spent talking about fields other than mathematics was about 2 hours. Homework was assigned daily and five exams, including a comprehensive final, were given.

Both instructors were careful not to incorporate any of the ideas, methods, or examples used in the interdisciplinary course into the traditional course in order to avoid the effect of "compensatory equalization of treatments" (Borg and Gall, 1989). In order to minimize the possiblity of the John Henry effect (Borg and Gall, 1989), students were not told that their class was being used as part of a research study.

The Experimental Group

The experimental group consisted of those students randomly assigned to the Algebra for the Sciences classes. The textbook used in the course was written by the two instructors of the course (Elliott and Oty), together with a faculty member from the Biological Sciences and a faculty member from the Physical Sciences. The instructional technique was primarily lecture with occasional demonstrations, making it quite similar to the instructional technique used in the comparison group. However, one of the instructors did use occasional group work in the interdisciplinary course. There were also frequent guest lectures by faculty from the various science areas. Most of the topics covered were similar to those in a traditional college algebra class such as lines, quadratics, exponentials, logarithms, and linear systems of equations. Other topics included were estimation, geometry, regression, and nonlinear systems of equations. The topics were introduced from a scientific viewpoint. For example, in the estimation chapter, a biologist gave the first lecture and talked about estimating the home range size of a thirteen-lined ground squirrel. Actual data gathered by the biologist were used in the discussions. These discussions led to the necessity of certain mathematical topics (liking estimating the area of an irregular shaped object or estimating the area under a curve). In the quadratic chapter, a physicist gave the first lecture and talked about gravity, also eventually leading to the need for more mathematics. Interdisciplinary projects were assigned at the end of each chapter. Homework was assigned daily and a midterm and comprehensive final exam were also given. The students in the course were not told that they were part of a research study, or that their class was any different than any of the other algebra classes and the instructors made sure that they continued to refer to the course as college algebra in order to minimize the occurence of the Hawthorne effect (Borg and Gall, 1989).

Procedures for Analysis of the Data

The data were analyzed using the statistical program JMP. Six independent t-tests were performed to test for a significant difference between the gain in critical thinking by those in the comparison group (College Algebra) and those in the experimental group (Algebra for the Sciences) as measured by the total score and five subscores of the WGCTA. Any test with a p-value less than .05 was reported as significant. A total of six tests were performed and the actual p-values are reported so the reader may elect to apply *Bonferroni's t-procedure* (Kirk, 1982) and as a result consider only p-values less than .01 to be significant. This results in the overall significance level remaining at about .05.

Analysis of variance and multiple regression were used to test for main effects and interaction effects between the other factors (gender, age, ethnicity, major, grade point average, Math ACT, Composite ACT, and grade in the course) and their effect on critical thinking skills. Again, all p-values less than .05 are reported as significant but the reader can choose in each case to apply *Bonferroni's t-procedure*.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

Comparing Characteristics of the Total Sample to Characteristics of the Population

A total of 211 students were enrolled in College Algebra under Oty or Elliott in the spring and fall of 1998. There were 32 different majors represented by these 211 students. Among the more common majors were: Undecided (42), Elementary Education (29), Biology (21), Management (14), Conservation (11), Computer Science (10), Music (8), Electronics (6), Health and Physical Education (6), Safety (6), Psychology (6), Sociology (5), and Prepharmacy (5). Of the 169 students that had declared a major, 69 were in the School of Science and Technology, 48 were in the School of Education and Behavioral Sciences, 26 were in the School of Arts and Letters, and 26 were in the School of Business.

There were 125 females (59%) and 86 males (41%). This is fairly close to the national average of 56% females and 44% males (NCES, 1998).

The ethnic breakdown of the sample was 82% White, 11% Native American, 4% African-American, 2% Hispanic and 1% Asian for a total minority percentage of 18%. Nationally, the breakdown is 75% White, 10% African-American, 8% Hispanic, 6% Asian, and 1% Native American for a total minority percentage of 25% (NCES, 1999). The low numbers of African-Americans, Hispanics and Asians in the sample made it impossible to reach meaningful conclusions about the effect of the interdisciplinary course on the critical thinking skills of those ethnic groups. However, there were a larger than usual number of Native Americans in the sample and conclusions were drawn about that particular ethnic group.

The mean age of the students in the sample was 21.4 and the median was 19.0. While this might be slightly older than the national average for a freshman level course, it represents a traditional group of students.

The mean Composite ACT score of the sample was 20.0. This is slightly lower than the national mean of 21.0 (ACT, 1998). The mean Math ACT score of the sample was 17.9, considerably lower than the national mean of 20.8 for all beginning freshmen but about average for freshmen whose first collegiate math course is an algebra course (ACT, 1998).

The mean critical thinking score of the sample at the beginning of the semester, as measured by the Watson Glaser Critical Thinking Appraisal (WGCTA), was 49.6. This falls between the national mean of high school seniors (48.5) and the national mean of freshmen in four-year colleges (53.8) (Watson and Glaser, 1980).

Comparing Characteristics of the Comparison Group and Experimental Group at the Beginning of the Semester

Even though the two groups were chosen completely at random, an analysis was done to determine if the two groups differed significantly in any major areas. In each case an independent t-test was performed to test for differences between the two groups. The results are given in Tables 1 and 2.

TABLE 1

Student Demographics

Class	N	GPA	Age	Fr/Soph%	ACT	Math ACT
Alg for Sci	93	2.75	22.6**	87%	19.3*	16.9**
College Alg	118	2.84	20.4	91%	20.5	18.7

*p<.05 **p<.01

TABLE 2

Critical Thinking Scores

Class	Inference	Assumption	Deduction	Interpretation	Evaluation	Overall
Alg for Sci	8.2	9.9	10.3*	11.3	10.9	50.6
College Alg	7.7	10.1	9.5	11.0	10.6	48.9

*p<.05 **p<.01

The two classes differing significantly in mean age was due to the fact that there were two outliers (students in their 60's) both in the Algebra for the Sciences class. If these two outliers were removed the mean age of the Algebra for the Sciences class would have been 21.6 and there would no longer be a statistically significant difference in the ages of the two classes. There was no significant difference between the median ages of the two classes. Even though there were significant differences in the ACT scores and the Deduction subscore of the WGCTA, not a lot of significance should be given this fact, especially considering that one class had the higher ACT's but the other class had the higher Deduction subscores. In addition, since a total of eleven comparisons were made, one might consider using *Bonferroni's t procedure* in order to not overinflate the probability of making a Type I error (rejecting a null hypothesis that is indeed true). In that case, each individual test should be tested at approximately the .005 level so that the overall significance level would be approximately .05. If this were done, none of the differences above would be statistically significant.

Differences in the Critical Thinking Gains of the Comparison Group and Experimental Group

Six independent t-tests were performed to determine if there were significant differences in the gains made between the experimental group and comparison group for each of the five critical thinking subscores and the overall critical thinking score. The assumptions for an independent t-test are that the distribution of the sample means is normally distributed and the two groups have equal variances. There was no need to test the normality assumption since there were well over 30 students in each group. The equal variance assumption was tested (at the .05 level) using Bartlett's test and was found to be satisfied in each case. The results from the t-tests are shown in Table 3.

TABLE 3

Comparing Critical Thinking Gains

	Alg. for Sci. (n=69)		College Alg. (n=72)		
	M	SE	M	SE	t
1. Inference	.16	.35	-.11	.34	.559
2. Assumption	.83	.50	.69	.49	.189
3. Deduction	-.28	.34	-.21	.33	-.140
4. Interpretation	.07	.32	.01	.33	-.121
5. Evaluation	.70	.32	.38	.32	.707
6. Overall Score	1.42	1.02	.82	1.00	.419

For the Inference subscore, the students in Algebra for the Sciences made an average gain of .16, while the students in College Algebra had their Inference subscore go down on average by .11. This did not represent a significant difference in gain (p=.5773).

For the Assumption subscore, the students in Algebra for the Sciences made an average gain of .83, while the students in College Algebra made an average gain of .69. This did not represent a significant difference in gain (p=.8507).

The students in both classes had their Deduction subscore decrease from Form A to Form B. The students in Algebra for the Sciences had their score go down by an average of .28 while those in College Algebra had theirs go down by .21. This did not represent a significant difference in decrease (p=.8888).

For the Interpretation subscore, the students in Algebra for the Sciences made an average gain of .01, while the students in College Algebra made an average gain of .07. This did not represent a significant difference in gain (p=.9040).

For the Evaluation subscore, the students in Algebra for the Sciences made an average gain of .70, while the students in College Algebra made an average gain of .38. This did not represent a significant difference in gain (p=.4808).

For the overall critical thinking score, the students in Algebra for the Sciences made an average gain of 1.42, while the students in College Algebra made an average gain of .82. This did not represent a significant difference in gain (p=.6756).

Tests were also run to determine if there was a significant difference between the comparison group and experimental group in the subscores and overall score of Form B of the WGCTA. Again, all assumptions were checked and found to be satisfied. The results are shown in Table 4.

TABLE 4

Comparing Critical Thinking (Form B)

	Alg. for Sci. (n=69)		College Alg. (n=72)		
	M	SE	M	SE	t
1. Inference	8.44	.28	7.66	.28	1.984*
2. Assumption	10.72	.39	10.37	.39	.631
3. Deduction	10.15	.31	9.45	.30	1.638
4. Interpretation	11.42	.29	11.15	.28	.673
5. Evaluation	11.56	.25	11.16	.25	1.123
6. Overall Score	52.30	.97	49.79	.96	1.834

* $p<.05$

The Algebra for the Sciences students scored higher than the College Algebra students in all five subscores and on the overall score. However, a statistically significant difference (at the .05 level) was found only on the Inference subscore ($p=.0492$) although the overall score was close ($p=.0687$).

Interactions Between the Other Factors and Course with Regards to Critical Thinking

Analysis of Variance and Standard Least Squares Regression procedures were run to determine which of the factors, if any, interact with the course. For each factor, a total of six tests were run, one for the gain in each of the five subscores of the WGCTA and one for the gain in the overall score. Using *Bonferroni's t procedure*, the individual significance levels should be set at something slightly less than .01 in order for the overall significance level to be approximately .05. However, so that the reader may determine for themselves what they consider to be significant, any individual test with a p-value less than .05 has been reported as statistically significant and the p-value has been stated.

Gender

Six two-way Analysis of Variances (ANOVA) with interaction were run with gender and course as the independent variables in each case and with the gain in each of the critical thinking subscores and overall score as the six dependent variables. Of interest was whether the interaction effect in each test was statistically significant. The results of each of these six tests are shown in Table 5.

TABLE 5

Testing for Interaction between Course and Gender

	F Ratio
1. Inference	<.00005
2. Assumption	1.9234
3. Deduction	.1432
4. Interpretation	6.6266*
5. Evaluation	.9042
6. Overall Score	.0923

* p<.05

The only variable with a significant interaction effect was Interpretation (p=.0111). The interaction effect was due to the fact that the males in Algebra for the Sciences had their Interpretation subscore go up by .57 while those in College Algebra had their Interpretation subscore go down by .84. The opposite was true for the females. The females in Algebra for the Sciences had their Interpretation subscore go down by .41 while those in College Algebra had their Interpretation subscore go up by .55.

School

Because of the large number of majors represented and thus the small sample size of certain majors, the students were classified according to which school their major belonged, the School of Arts and Letters, the School of Business, the School of Education, or the School of Science and Technology. A fifth category was also created for those students who had not decided on a major. Six two-way Analysis of Variances (ANOVA) with interaction were then run with school and course as the independent variables in each case and with the gain in each of the critical thinking subscores and overall score as the six dependent variables. The results of these six tests are shown in Table 6. There were no significant interaction effects.

TABLE 6

Testing for Interaction between Course and School

	F Ratio
1. Inference	.8786
2. Assumption	.7673
3. Deduction	.5506
4. Interpretation	.3043
5. Evaluation	1.0311
6. Overall Score	.8663

Ethnicity (Whites and Native Americans only)

Six two-way Analysis of Variances (ANOVA) with interaction were run with ethnicity and course as the independent variables in each case and with the gain in each of the critical thinking subscores and the overall score as the six dependent variables. The results of each of these six tests are shown in Table 7. There were no significant interaction effects.

TABLE 7

Testing for Interaction between Course and Ethnicity

	F Ratio
1. Inference	.0543
2. Assumption	.4602
3. Deduction	.0287
4. Interpretation	.0560
5. Evaluation	1.3304
6. Overall Score	.0038

Grade Point Average

Six standard least squares regressions were performed with GPA, course and the interaction between them as the independent variables and with the gain in each of the critical thinking subscores and overall score as the dependent variables. The results of each of these six tests are shown in Table 8. There were no significant interaction effects.

TABLE 8

Testing for Interaction between Course and GPA

	F Ratio
1. Inference	.8115
2. Assumption	1.3300
3. Deduction	.7125
4. Interpretation	.3158
5. Evaluation	1.7003
6. Overall Score	3.0029

Grade in the Course

Six standard least squares regressions were performed with grade in the course, course, and the interaction between them as the independent variables and with the gain in each of the critical thinking subscores and overall score as the dependent variables. The results of each of these six tests are shown in Table 9.

TABLE 9

Testing for Interaction between Course and Grade

	F Ratio
1. Inference	.0161
2. Assumption	.5948
3. Deduction	4.3605*
4. Interpretation	.4659
5. Evaluation	.5856
6. Overall Score	1.2724

* $p<.05$

The only variable with a significant interaction effect was Deduction ($p=.0387$). The interaction effect was due to the fact that in the Algebra for the

Sciences class there was a slightly negative correlation (-.12) between the grade received in the class and the gain made on the deduction subscore, whereas in the College Algebra class there was a slightly positive correlation (.22).

Age

Six standard least squares regressions were performed with age, course, and the interaction between them as the independent variables and with the gain in each of the critical thinking subscores and overall score as the six dependent variables. The results of these six tests are shown in Table 10. There were no significant interaction effects.

TABLE 10

Testing for Interaction between Course and Age

	F Ratio
1. Inference	.8361
2. Assumption	.5855
3. Deduction	.4830
4. Interpretation	.3746
5. Evaluation	1.3144
6. Overall Score	.1510

Composite ACT

Six standard least squares regressions were performed with Composite ACT, course , and the interaction between them as the independent variables and with the gain in each of the critical thinking subscores and overall score as the dependent variables. The results are shown in Table 11. There were no significant interaction effects.

TABLE 11

Testing for Interaction between Course and Composite ACT

	F Ratio
1. Inference	.2472
2. Assumption	.3782
3. Deduction	.1723
4. Interpretation	.6316
5. Evaluation	.8351
6. Overall Score	.4586

Math ACT

Six standard least squares regressions were performed with Math ACT, course, and the interaction between them as the independent variables and with the gain in each of the critical thinking subscores and overall score as the six dependent variables. The results are shown in Table 12. There were no significant interaction effects.

TABLE 12

Testing for Interaction between Course and Math ACT

	F Ratio
1. Inference	.0638
2. Assumption	3.4501
3. Deduction	.0068
4. Interpretation	.0045
5. Evaluation	1.0236
6. Overall Score	1.3601

Classification

There were not enough upper-level students in the two courses to test for significant interactions between classification and course with regards to critical thinking. Even if such a test had been possible it would probably have been a virtual mirror of the interaction test given above for Age and course with regards to critical thinking (in which no significant interactions were found).

Other Factors' Relationships to Critical Thinking

Tests were also run to determine what other factors influence students' critical thinking skills. T-tests, ANOVA's or simple correlations were performed for each of the factors depending upon their level of measurement. For each of the tests given below, course was not considered. Instead, the analysis was done on all eight classes combined.

College Attendance

Six one-tailed paired t-tests were performed to determine if the students made a significant gain from the score on Form A to the score on Form B for each of the five subscores and the overall score of the WGCTA. The results of these tests are shown in Table 13.

TABLE 13

Testing for Significant Gain from Form A to Form B

	Form A (n=145)		Form B (n=145)		
	M	SE	M	SE	t
1. Inference	8.0	.223	8.1	.198	.03
2. Assumption	10.0	.304	10.5	.278	1.93*
3. Deduction	9.8	.206	9.8	.215	-.98
4. Interpretation	11.1	.198	11.3	.201	.12
5. Evaluation	10.7	.231	11.4	.178	2.38**
6. Overall Score	49.6	.711	51.0	.685	1.43

* $p < .05$

** $p < .01$

The only subscore on which the students' average score went down (but not significantly so) was the Deduction subscore. On the other four subscores and on the overall score the students made gains. Two of the gains were statistically significant. These were the gains made in the Assumption (p=.0276) and the Evaluation (p=.0093) subscores. Only the gain in the Evaluation subscore would be significant when considering the number of tests run and using *Bonferonni's t procedure*. Although the gain in the overall score was not significant, it was fairly close with a p-value of .0777.

Level of Student

Independent t-tests were performed to see if upper level students (juniors and seniors) differed significantly from lower level students (freshmen and sophomores) in critical thinking. These t-tests were done for Form A, Form B, and the gain made in critical thinking (Form B - Form A). The equal variance assumption was also tested in each case using Bartlett's (1937) test. The results of the t- tests are shown in Table 14.

TABLE 14

Testing for Difference in Upper and Lower Level Students

	Lower Level		Upper Level		
	M	SE	M	SE	t
1. Inference (A)	8.0	.20	7.6	.57	.572
2. Assumption (A)	10.1	.27	9.2	.78	1.052
3. Deduction (A)	9.8	.18	10.5	.52	1.408
4. Interpretation (A)	11.1	.18	11.1	.51	.015
5. Evaluation (A)	11.2	.19	11.1	.60	.612[a]
6. Overall Score (A)	49.7	.63	48.8	1.82	.500
7. Inference (B)	8.0	.21	8.4	.69	.560
8. Assumption (B)	10.5	.29	10.8	.96	.267
9. Deduction (B)	9.8	.22	10.1	.75	.386
10. Interpretation (B)	11.3	.21	11.6	.70	.439
11. Evaluation (B)	11.4	.19	11.0	.62	.640
12. Overall Score (B)	51.0	.72	51.8	2.38	.353
13. Inference (Gain)	-.12	.25	1.33	.82	1.690
14. Assumption (Gain)	.48	.37	2.92	1.20	1.940
15. Deduction (Gain)	-.22	.25	-.33	.82	.129
16. Interpretation (Gain)	-.02	.24	.58	.78	.747
17. Evaluation (Gain)	.48	.24	1.17	.77	.853
18. Overall (Gain)	.59	.74	5.67	2.43	2.000*

Note. For Form A there were 182 Lower Level and 22 Upper Level students. For Form B there were 133 Lower Level and 12 Upper Level students. For the gains made there were 130 Lower Level and 12 Upper Level students.

[a]Welch's (1947) nonparametric test was used due to unequal variances. * $p < .05$

The only significant difference found was in the overall gain (p=.0480). The upper level students had an average gain of 5.67 points while the lower level students had an average gain of 0.59. It should be noted that the upper level students in this sample were not representative of most upper level students because they chose to take a freshmen level math course in the latter part of their collegiate career.

Gender

Independent t-tests were performed to determine if there were significant differences between males and females on each of the five subscores and the overall score of the WGCTA. These tests were performed for Form A, Form B and for the gain in critical thinking (Form B - Form A). The results of the t-tests are given in Table 15.

TABLE 15

Testing for Difference in Males and Females

	Females		Males		
	M	SE	M	SE	t
1. Inference (A)	7.7	.24	8.4	.30	1.844
2. Assumption (A)	9.8	.33	10.3	.41	1.020
3. Deduction (A)	9.8	.22	10.0	.27	.597
4. Interpretation (A)	11.0	.21	11.2	.26	.667
5. Evaluation (A)	11.4	.21	11.1	.58	1.421[a]
6. Overall Score (A)	49.2	.77	50.3	.95	.885
7. Inference (B)	8.1	.26	7.9	.31	.413
8. Assumption (B)	10.5	.36	10.6	.44	.193
9. Deduction (B)	9.6	.28	10.1	.34	1.130
10. Interpretation (B)	11.2	.26	11.4	.32	.294
11. Evaluation (B)	11.7	.23	10.9	.28	2.168*
12. Overall Score (B)	51.1	.88	50.9	1.08	.156
13. Inference (Gain)	.34	.30	-.53	.38	1.782
14. Assumption (Gain)	.84	.45	.44	.57	.554
15. Deduction (Gain)	-.39	.30	.02	.38	.840
16. Interpretation (Gain)	.09	.29	-.07	.36	.355
17. Evaluation (Gain)	1.11	.26	.58	.57	.804[a]
18. Overall (Gain)	1.57	.91	.15	1.15	.974

Note. For Form A there were 123 females and 81 males. For Form B there were 87 females and 58 males. For the gains made there were 87 females and 55 males.

[a]Welch's nonparametric test was used due to unequal variances. * $p < .05$

The only significant difference found was on the Evaluation subscore of Form B. The females scored significantly higher making an average of 11.7 (out of a possible 16) compared to the males' average of 10.9 ($p=.0318$).

Major

Because of the range of majors represented in this study, and because there were very small sample sizes in some of the majors, the students were classified according to the schools to which their majors belonged. Southeastern Oklahoma State University is divided into four schools: Arts and Letters (AL), Business (BUS), Education and Behavioral Sciences (ED), and Science and Technology (ST). Additionally, students who indicated that their major was Undecided (UND) formed the fifth group. Oneway Analysis of Variance was done to determine if any differences exist in the critical thinking of students in different schools. This was done for the overall score and each of the five subscores of the WGCTA for Form A, Form B and the gain made from Form A to Form B (Form B - Form A) for a total of six tests. The assumption of equal variances was tested using Bartlett's test and was found to be satisfied in each case. If significant differences were found in the means, then a Multiple Comparison test was run to determine where those differences were. The means and F values for Form A are given in Table 16.

TABLE 16

Testing for Differences in Schools (Form A)

	AL(n=24)	BUS(n=25)	ED(n=49)	ST(n=65)	UND(n=41)	F
1. Inference	8.4	7.2	7.8	8.3	7.8	.985
2. Assumption	10.9	9.4	10.0	10.4	9.2	1.221
3. Deduction	10.3	9.3	9.8	10.2	9.3	1.399
4. Interpretation	11.3	11.3	10.9	11.4	10.7	.725
5. Evaluation	11.3	11.3	10.3	11.1	10.0	1.762
6. Overall	52.2	48.5	48.8	51.4	47.0	2.483*

*$p < .05$

No significant differences were found between the schools in any of the subscores of Form A of the WGCTA. However, a significant difference was found in the overall score of Form A ($p=.0450$). Out of a possible 80 points, the students in the School of Arts and Letters scored the highest with an average of 52.2. This was followed by the School of Science and Technology with 51.4, the School of Education and Behavioral Sciences with 48.8, the School of Business with 48.5, and the Undecided students with 47.0. Using a multiple comparison test, significant differences were found between the Undecided students and those students that were in either the School of Arts and Letters or the School of Science and Technology. The means and F values for Form B are shown in Table 17.

TABLE 17

Testing for Differences in Schools (Form B)

	AL(n=24)	BUS(n=25)	ED(n=49)	ST(n=65)	UND(n=41)	F
1. Inference	9.3	7.2	7.4	8.6	7.9	3.014*
2. Assumption	10.9	9.2	10.1	11.2	10.4	1.452
3. Deduction	10.5	9.5	9.3	10.4	9.1	1.882
4. Interpretation	12.1	11.4	11.2	11.4	10.7	.778
5. Evaluation	12.1	11.7	11.0	11.4	11.2	.718
6. Overall	54.8	48.9	49.0	53.1	49.4	2.699*

*$p < .05$

On Form B, significant differences were found on the Inference subscore (p=.0202) and on the overall score (p=.0332). Out of a possible 16 points on the inference subscore, the students in the School of Arts and Letters again scored the highest with an average of 9.3, followed by the School of Science and Technology with 8.6, the Undecideds with 7.9, the School of Education and Behavioral Sciences with 7.4, and the School of Business with 7.2. This represents a significant difference between those students in either the School of Arts and Letters or the School of Science and Technology and those students that are in either the School of Education and Behavioral Sciences or the School of Business. On the overall score of Form B, the students in the School of Arts and Letters again scored highest with an average of 54.8, compared to 53.1 for the School of Science and Technology, 49.4 for the Undecideds, 49.0 for the School of Education and Behavioral Sciences and 48.9 for the School of Business. This represents a significant difference between those students in either the School of Arts and Letters or the School of Science and Technology and those students in the School of Education. The means and F values for the gain made from Form A to Form B are shown in Table 18.

TABLE 18

Testing for Differences in Schools (Gain)

	AL(n=24)	BUS(n=25)	ED(n=49)	ST(n=65)	UND(n=41)	F
1. Inference	-.67	.00	-.24	.51	-.26	.668
2. Assumption	.17	-.29	.76	.80	1.22	.389
3. Deduction	-.92	.29	-.49	.16	-.63	.769
4. Interpretation	.08	.29	.22	.04	-.44	.291
5. Evaluation	.50	.06	.68	.59	.56	.162
6. Overall	-.83	.35	.92	2.10	.44	.391

On the gain made from Form A to Form B (Form B - Form A) no significant differences were found between students in the different schools. In general, the scores for Assumption, Interpretation, Evaluation and the overall score went up from Form A to Form B for the majority of students, while the scores for Inference and Deduction went down for the majority of students.

Ethnicity

Because of the low numbers of Asians, African-Americans and Hispanics in the sample, only tests comparing Whites and Native Americans were run. Independent t-tests were run to determine if there were significant differences in the average scores of Whites and Native Americans on Form A, Form B and the gain made from Form A to Form B (Form B - Form A). The assumption of equal variances was also tested and was found to be satisfied in each case. The results from the t-tests are given in Table 19.

TABLE 19

Testing for Difference in Native Americans and Whites

	Native Americans		Whites		
	M	SE	M	SE	t
1. Inference (A)	7.1	.53	8.2	.20	1.762
2. Assumption (A)	9.7	.75	10.1	.28	.557
3. Deduction (A)	9.3	.49	10.0	.19	1.217
4. Interpretation (A)	11.2	.48	11.1	.18	.056
5. Evaluation (A)	9.8	.58	10.8	.22	1.705
6. Overall Score (A)	47.0	1.73	50.1	.66	1.688
7. Inference (B)	8.4	.58	8.0	.22	.606
8. Assumption (B)	10.8	.83	10.4	.32	.445
9. Deduction (B)	8.8	.63	10.1	.24	1.857
10. Interpretation (B)	10.8	.59	11.4	.23	.882
11. Evaluation (B)	11.3	.52	11.5	.20	.386
12. Overall Score (B)	50.1	2.01	51.4	.77	.578
13. Inference (Gain)	1.35	.68	-.17	.26	2.075*
14. Assumption (Gain)	1.41	1.02	.34	.39	.980
15. Deduction (Gain)	-.44	.62	.02	.27	.863[a]
16. Interpretation (Gain)	-.24	.66	.00	.25	.333
17. Evaluation (Gain)	1.29	.65	.62	.25	.966
18. Overall (Gain)	2.82	2.09	.66	.81	.967

Note. For Form A and Form B there were 17 Native Americans and 116 Whites.

For the gains made there were 17 Native Americans and 114 Whites.

[a]Welch's nonparametric test was used due to unequal variances. * $p < .05$

The only significant difference found was in the gain made on the Inference subscore (p=.0400). The Native Americans went from an average score of 7.06 on Form A to 8.41 on Form B for an average gain of 1.35. The Whites, on the other hand, went from an average score of 8.20 on Form A to 8.03 on Form B for an average loss of .17.

Grade in the Class

Pearson correlation coefficients were calculated between grade received in the class and each subscore as well as the overall score of the WGCTA for both Form A and Form B. The results are given in Table 20.

TABLE 20

Correlations Between Critical Thinking and Grade

Critical Thinking Measure	Correlation
Inference (A)	.2552**
Assumption (A)	.0629
Deduction (A)	.2682**
Interpretation (A)	.2443**
Evaluation (A)	.1460
Overall Score (A)	.2985**
Inference (B)	.3188**
Assumption (B)	.1655*
Deduction (B)	.3573**
Interpretation (B)	.2856**
Evaluation Subscore Form B	.2445**
Overall Score Form B	.4181**

* $p < .05$

** $p < .01$

Grade Point Average (GPA)

Pearson correlation coefficients were calculated between grade point average at the beginning of the semester and each subscore as well as the overall score of the WGCTA for both Form A and Form B. The results are given in Table 21.

TABLE 21

Correlations Between Critical Thinking and GPA

Critical Thinking Measure	Correlation
Inference (A)	.0988
Assumption (A)	.0683
Deduction (A)	.1864*
Interpretation (A)	.2449**
Evaluation (A)	.1890*
Overall Score (A)	.2397**
Inference (B)	.3386**
Assumption (B)	.0386
Deduction (B)	.2223*
Interpretation (B)	.4269**
Evaluation (B)	.3452**
Overall Score (B)	.4421**

* $p < .05$ ** $p < .01$

Age

Pearson correlation coefficients were calculated between age at the beginning of the semester and each subscore as well as the overall score of the WGCTA for both Form A and Form B. The results are given in Table 22.

TABLE 22

Correlations Between Critical Thinking and Age

Critical Thinking Measure	Correlation
Inference (A)	.1916**
Assumption (A)	-.0015
Deduction (A)	.1201
Interpretation (A)	.1080
Evaluation (A)	-.0365
Overall Score (A)	.1125
Inference (B)	.1366
Assumption (B)	.0067
Deduction (B)	.0275
Interpretation (B)	.2490**
Evaluation (B)	.0313
Overall Score (B)	.1320

** $p < .01$

Math ACT

Pearson correlation coefficients were calculated between the mathematics portion of the ACT, and each subscore as well as the overall score of the WGCTA for both Form A and Form B. The results are given in Table 23.

TABLE 23

Correlations Between Critical Thinking and Math ACT

Critical Thinking Measure	Correlation
Inference (A)	.1481*
Assumption (A)	.0418
Deduction (A)	.1911**
Interpretation (A)	.2492**
Evaluation (A)	.1572*
Overall Score (A)	.2366**
Inference (B)	.2734**
Assumption (B)	.1081
Deduction (B)	.3404**
Interpretation (B)	.3431**
Evaluation (B)	.1996*
Overall Score (B)	.3813**

* $p < .05$ ** $p < .01$

Composite ACT

Pearson correlation coefficients were calculated between the composite ACT, and each subscore as well as the overall score of the WGCTA for both Form A and Form B. The results are given in Table 24.

TABLE 24

Correlations Between Critical Thinking and Composite ACT

Critical Thinking Measure	Correlation
Inference (A)	.3258**
Assumption (A)	.1315
Deduction (A)	.2773**
Interpretation (A)	.4055**
Evaluation (A)	.2787**
Overall Score (A)	.4365**
Inference (B)	.4018**
Assumption (B)	.2075*
Deduction (B)	.4564**
Interpretation (B)	.4947**
Evaluation (B)	.3482**
Overall Score (B)	.5778**

* $p < .05$ ** $p < .01$

In addition to the above correlations, multiple forward stepwise regression was performed to determine which single variable was the most significant predictor of each of the critical thinking subscores and overall scores. Composite ACT was found to be the most significant predictor for each subscore and the overall score of Form A (taken at the beginning of the semester). For Form B, Composite ACT was again the most significant predictor for the subscores Assumption, Interpretation, and Evaluation as well as the overall score. However, GPA was the most significant predictor of the Inference subscore and grade received in the course was the most significant predictor of the Deduction subscore.

Correlations between scores on Form A and the gain made
from Form A to Form B

Correlations were run to determine if students who began the semester with weak critical thinking skills gained more from a semester of college than students who already had strong critical thinking skills. Correlations were run between the scores on Form A and the gain made from Form A to Form B (Form B - Form A). A significant negative correlation would indicate that the students with weaker critical thinking skills do benefit more (since larger Form A scores would be associated with smaller gains). The results are shown in Table 25.

TABLE 25

Correlations Between Form A and Gain

Critical Thinking Measure	Correlation
Inference	-.65**
Assumption	-.64**
Deduction	-.52**
Interpretation	-.55**
Evaluation	-.67**
Overall Score	-.54**

** $p < .01$

The results in Table 25 indicate that (as would be expected) there is a relationship between entering critical thinking ability and the amount of improvement made in critical thinking. That is, students with strong critical thinking skills did not have as much room for improvement as students who began the semester with weak critical thinking skills.

CHAPTER FIVE

SUMMARY OF FINDINGS, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

Did the Algebra for the Sciences Course Enhance Critical Thinking More than the College Algebra Course?

The first hypothesis tested in this study was:

Students who take an interdisciplinary algebra course will improve significantly more in critical thinking ability than students who take a traditional college algebra course. This will be true, not only for overall critical thinking, but also for specific areas of critical thinking such as inference, recognition of assumptions, deduction, interpretation and evaluation of arguments.

The students in the interdisciplinary algebra course (Algebra for the Sciences) had higher gains in critical thinking than the students in the College Algebra course in the overall critical thinking score and in four of the five subscores (Inference, Assumptions, Deduction, and Evaluation) as measured by the Watson-Glaser Critical Thinking Appraisal (WGCTA). However, those gains were not statistically significant.

One possible explanation for the lack of significance is that the students in Algebra for the Sciences had slightly better critical thinking scores at the beginning of the semester than the College Algebra students. It has been shown by Dressel and Mayhew (1954) that students with weak critical thinking skills show greater gains during their first year of college than students with strong critical thinking skills. Therefore, it could be considered positive that the difference was in the direction hypothesized even though it was not significant. If comparisons are made between the two groups' scores on Form B of the WGCTA (taken at the end of the semester) instead of the gains made, it is found that the Algebra for the Sciences students did better than the college algebra students on all five subscores and the overall score. On the Inference subscore the difference was statistically significant.

Another possible explanation for the lack of significant difference in the gains made was instructor experience. The two courses were taught by instructors who had taught over 40 sections of College Algebra between the two of them. Thus, they were very familiar with the course and taught the course in a very organized fashion. On the other hand, Algebra for the Sciences was a brand new course and had never been taught before. In addition, since it was a combination of algebra and science, the instructors had to learn a lot of science as well. Now in their third semester of teaching the course, both instructors feel much more comfortable with the course. Unfortunately, only the first two semesters worth of data were included in this study.

The lack of significance in the gains made does agree with Beckman (1956) who found that courses in argumentation and discussion did not improve critical thinking and with Dressel and Mayhew (1954) and Lyle (1958) who found that courses that emphasized critical thinking did not enhance critical thinking.

Did Other Factors Affect Which Course Increased Critical Thinking the Most?

The second hypothesis tested in this study was:

There will be no significant interaction between type of course (interdisciplinary vs. traditional) and any of the other factors (gender, major, ethnicity, grade point average, grade in the course, age, Composite ACT, and Math ACT).

Gender

In terms of critical thinking scores as measured by the WGCTA, the males did better in each of the subscores and the overall score by taking Algebra for the Sciences. The females were also better served by the Algebra for the Sciences course in four of the subscores and the overall score. However, for the Interpretation subscore, the females did significantly better ($p=.0111$) taking the traditional College Algebra course. One possible explanation for this is that in at least two of the four College Algebra classes the students that were most involved in the classroom discussions were females. In at least two of the Algebra for the Sciences classes the most involved students were males. Volkwein, King and Terenzini (1986) found that classroom involvement had the strongest association with intellectual skill development.

Major

Because of the large number of different majors represented and thus the small sample sizes within some majors, the students were classified according to the school to which their major belonged. No significant interaction was found between the school to which one's major belonged and the course with regards to critical thinking. That is, the school to which a student's major belonged had no bearing on which course the student should take to increase their critical thinking skills the most.

Ethnicity

Because of the small numbers of African-Americans, Hispanics and Asians, only Whites and Native Americans were considered. No significant interaction was found between ethnicity and the course with regards to critical thinking. That is, the student's ethnic background had no bearing on which course the student should take to increase their critical thinking skills the most. Although many previous studies have been done comparing the critical thinking abilities of African-Americans and Whites, none could be found that compared the critical thinking abilities of Whites and Native Americans.

Grade Point Average

No significant interaction was found between GPA and the course with regards to critical thinking. That is, the student's GPA had no bearing on which course the student should take to increase their critical thinking skills the most. No previous studies could be found examining whether interdisciplinary courses were more or less beneficial to students with high or low GPA's.

Grade in the Course

The only significant interaction ($p=.0387$) found between grade and the course was with regards to the Deduction subscore. In the Algebra for the Sciences course there was a slightly negative correlation (-.12) between the grade received in the course and the gain made on the Deduction subscore and in College Algebra there was a slightly positive correlation (.22). One explanation for this could be that the Algebra for the Sciences students entered the course with significantly higher Deduction subscores (See Table 1). Another explanation could be the types of problems normally presented in the Algebra for the Sciences course. The students spent considerable time looking for patterns in data and reasoning from the specific to the general (induction). However, little emphasis was put on reasoning from the general to the specific (deduction). In terms of the other subscores and the overall score, the students were better served by taking the Algebra for the Sciences course.

Age

No significant interaction was found between age and the course with regards to critical thinking. That is, the student's age had no bearing on which course the student should take to increase their critical thinking skills the most. Students of both traditional ages and nontraditional ages benefitted more, in terms of critical thinking ability, from the Algebra for the Sciences class.

Composite ACT

No significant interaction was found between Composite ACT and the course with regards to critical thinking. That is, the student's Composite ACT score had no bearing on which course the student should take to increase their critical thinking skills the most.

Math ACT

No significant interaction was found between Math ACT and the course with regards to critical thinking. That is, the student's Math ACT score had no bearing on which course the student should take to increase their critical thinking skills the most.

What Other Factors are Related to Critical Thinking?

A third purpose of this study was to determine what other factors are related to critical thinking, and to see how the results compare with the findings of other researchers.

College Attendance

McMillan (1987) found in an extensive review of twenty-seven separate studies that college attendance enhances critical thinking. Using the WGCTA, Pascarella (1989) found that college students in their first year made significant gains in the Interpretation and Evaluation subscores and on the overall score, but did not make significant gains in the other three subscores (Inference, Assumption and Deduction).

In this study, the students made significant gains in Assumption ($p=.0276$) and Evaluation ($p=.0093$) but not in the other three subscores nor in the overall score. However, the overall score's gain was close to being significant with a p-value of .0777. It should also be noted that in Pascarella's study, the students were retested after a year of college and in this study it was after only a semester. Given a longer period of time, or more students to test, this study would likely have found statistical significance in the overall score as well (although the practical significance of such a result could still be debated). The combined results of these studies indicates that students make significant gains in the Evaluation subscore during their first year of college. The WGCTA manual (Watson and Glaser, 1980, p. 2) states that the Evaluation subscore measures the student's ability to distinguish "between arguments that are strong and relevant and those that are weak or irrelevant to a particular question at issue."

Level of Student

A similar question to "Does college attendance affect critical thinking?" is the question "Do students with more college credits perform better on measures of critical thinking?" Steinberg and Shapiro (1982) found the answer to the second question to be yes.

In this study, students were classified as lower level (freshman or sophomore) or upper level (junior, senior or graduate). No significant differences were found in the critical thinking ability of the two groups, either at the beginning or the end of the semester. At first thought, this seems to contradict the findings of Steinberg and Shapiro. Upon closer inspection, however, one realizes that the upper level students in this study are not representative of most upper level students because they chose to take a freshman level mathematics course toward the end of their collegiate career.

Gender

The WGCTA manual (Watson and Glaser, 1980, p. 7) states that "differences between sexes were examined in preliminary data analyses, and no consistent differences were found between males and females." Other studies that used the WGCTA also found no differences between males and females in their critical thinking ability (see e.g., Burns, 1974; Gurfein, 1977; Simon and Ward, 1974).

In this study, no significant differences were found between the males' and females' critical thinking scores at the beginning of the semester as measured by Form A of the WGCTA. At the end of the semester, females scored significantly higher than the males on the Evaluation subscore ($p=.0318$) as measured by Form B of the WGCTA. Because of the large number of tests performed here, one may wish to use *Bonferroni's t-procedure* in which case this difference would no longer be statistically significant. Therefore, the results in this study agree with the results found by previous researchers that no differences exist in the critical thinking abilities of males and females.

Major

Several studies have been done to examine how academic major is related to critical thinking. Kitchener (1977) found that academic major may be a factor related to reflective judgment (a concept closely related to critical thinking). Pohl and Pervin (1968) found that applied science majors scored significantly lower in cognitive complexity than liberal arts majors. Others (see, e.g., Spaulding and Kleiner, 1992; Keeley, Browne and Kreutzer, 1982; Welfel, 1982) have found that academic major is not a factor in critical thinking.

Because of the wide variety of majors, and thus a small sample size within each major, students in this study were classified according to the school to which their academic major belonged. Southeastern Oklahoma State University is divided into four schools: Arts and Letters, Business, Education and Behavioral Sciences, and Science and Technology. Additionally, students who indicated that their major was Undecided (UND) formed the fifth group.

No significant differences were found on any of the subscores of Form A of the WGCTA. However, a significant difference was found in the overall score of Form A (p=.0450). The students in the School of Arts and Letters or the School of Science and Technology scored significantly higher than the students that were undecided about their academic major.

On Form B, students in the School of Education scored significantly lower than students in either the School of Arts and Letters or the School of Science and Technology on both the overall score (p=.0332) and the Inference subscore (p=.0202). Students in the School of Business scored significantly lower on the Inference subscore but not the overall score than students in either the School of Arts and Letters or the School of Science and Technology.

These results seem to agree most with Kitchener (1981) that academic major may be a factor in critical thinking. They also seem to contradict Pohl and Pervin who found that applied science majors scored lower on cognitive complexity. One explanation for this discrepancy is that cognitive complexity and critical thinking are not synonymous. Neither Kitchener nor Pohl and Pervin used the WGCTA as their measure of critical thinking. Of the researchers who did use the WGCTA, none found differences according to academic major. Again, because of the large number of tests run, one may wish to apply *Bonferroni's t-procedure* in which case no significant differences would have been found in this study as well.

Ethnicity

In this study, the only two groups with large enough numbers to be compared were Whites and Native Americans. Very few, if any, studies have been done comparing the critical thinking abilities of these two groups. No significant differences were found between the two groups on either Form A or Form B of the WGCTA. A significant difference was found, however, on the gain made from Form A to Form B for the Inference subscore (p=.0400). The Native Americans made a significant gain from 7.06 to 8.41 while the Whites actually had a slight decrease from 8.20 to 8.03. Inference is defined in the WGCTA manual as "Discriminating among degrees of truth or falsity of inferences drawn from given data (Watson and Glaser, 1980, p.2). Perhaps cultural differences between the two groups could account for this difference.

Grade in the Class

Pascarella (1991) found a significant correlation between critical thinking and grade received in a freshman course. The WGCTA manual (Watson and Glaser, 1980, p.12) reports a correlation of .16 between grade in a freshman course and the score on Form A and a correlation of .35 between grade in a freshman course and the score on Form B. The first of these two correlations is not reported as statistically significant but the second one is reported as significant at the .05 level.

The results of this study certainly agree with both Pascarella (1991) and Watson and Glaser (1980). On Form A, the correlation between grade in the course and overall critical thinking score was .30 which is statistically significant at the .01 level ($p=.0001$). The Inference, Deduction and Interpretation subscores had correlations of .26, .27, and .24 respectively, all of which were statistically significant at the .01 level.

On Form B, the correlation between grade in the course and overall critical thinking score was .42 which was statistically significant at the .01 level ($p<.00005$). The Inference, Deduction, Interpretation, Evaluation and Assumption subscores had correlations of .32, .36, .29, .24 and .17 respectively. The first four of these were statistically significant at the .01 level and the last one (Assumption) was statistically significant at the .05 level. As indicated in the WGCTA manual, score on Form B was more highly correlated with grade in course than was score on Form A. It is clear from these results that grade in a freshman course is significantly related to a student's critical thinking ability.

Grade Point Average (GPA)

Spaulding and Klein (1992) found a significant correlation between critical thinking and grade point average. The WGCTA manual reports a correlation of .12 between score on Form A and the grade point average of students at a small college in the Northeast. (Watson and Glaser, 1980, p.12). This correlation is not statistically significant. It also reports a correlation of .30 between critical thinking and grade point average of freshmen at a university in the South. This correlation is significant at the .05 level. Similar, though slightly stronger, results were found in this study.

On Form A, the correlation between grade point average and overall critical thinking score was .24 which was statistically significant at the .01 level (p=.0027). The Deduction, Evaluation and Interpretation subscores had correlations of .19, .19, and .24 respectively, with the first two being statistically significant at the .05 level and the third one at the .01 level.

On Form B, the correlation between grade point average and overall critical thinking score was .37 which was statistically significant at the .01 level (p=.0001). The Inference, Evaluation, Interpretation, and Deduction subscores had correlations of .34, .24, .43, and .22 respectively. The first three of these were statistically significant at the .01 level and the last one (Deduction) was statistically significant at the .05 level. It is clear from these results that grade point average is significantly related to a student's critical thinking ability.

Age

Two significant relationships were found between age and critical thinking in this study. A statistically significant (p=.0060) positive correlation (.19) was found between age and the Inference subscore of Form A. A statistically significant (p=.0025) positive correlation (.25) was also found between age and the Interpretation subscore of Form B. This means that the older students did significantly better on these two subscores than the younger students. A more surprising result may be that none of the other subscores nor overall scores were significantly correlated with age.

Math ACT

The WGCTA manual reports a correlation of .30 between Math ACT and scores on Form A for nursing students at a university in the West. This correlation is not statistically significant at the .05 level (probably due to the small sample size N=24). Similar results were found in this study.

On Form A, the correlation between Math ACT and overall critical thinking score was .24 which was statistically significant at the .01 level (p=.0013). The

Deduction, Interpretation, Inference and Evaluation subscores had correlations of .19, .25, .15, and .16 respectively, with the first two being statistically significant at the .01 level and the last two at the .05 level.

On Form B, the correlation between Math ACT and overall critical thinking score was .38 which was statistically significant at the .01 level ($p<.00005$). The Inference, Deduction, Interpretation, and Evaluation subscores had correlations of .27, .34, .34, and .20 respectively. The first three of these were statistically significant at the .01 level and the last one (Evaluation) was statistically significant at the .05 level. It is clear from these results that Math ACT is significantly related to a student's critical thinking ability.

Composite ACT

The WGCTA manual reports a correlation of .65 between Composite ACT and critical thinking scores for freshmen at a university in the South. This correlation is statistically significant at the .01 level. Similar results were found in this study.

On Form A, the correlation between Composite ACT and overall critical thinking score was .44 which was statistically significant at the .01 level ($p<.00005$). The Deduction, Interpretation, Inference and Evaluation subscores had correlations of .28, .41, .33, and .28 respectively, with all of them being statistically significant at the .01 level.

On Form B, the correlation between Composite ACT and overall critical thinking score was .58 which was statistically significant at the .01 level ($p<.00005$). The Inference, Evaluation, Deduction, Interpretation, and Assumption subscores had correlations of .40, .35, .46, .50, and .20 respectively. The first four of these were statistically significant at the .01 level and the last one (Assumption) was statistically significant at the .05 level. It is clear from these results that Composite ACT is significantly related to a student's critical thinking ability.

Comparing the Gain Made by Students With Weak Critical Thinking Skills and the Gain Made by Students With Strong Critical Thinking Skills

Dressel and Mayhew (1954) found, as one would expect, that students with the lowest pretest scores showed the greatest gains in critical thinking. This proved to be true in this study as well. The correlation between overall score on Form A and overall gain made from Form A to Form B was -.54. This correlation was significant at the .01 level ($p<.00005$). The Inference, Assumption, Deduction, Interpretation and Evaluation subscores had correlations of -.65, -.64, -.52, -.55, and -.67 respectively. Each of these correlations were statistically significant at the .01 level.

Summary

Students in the interdisciplinary course Algebra for the Sciences made greater gains in critical thinking than students in the traditional College Algebra. However, these gains were not statistically significant. In terms of overall critical thinking, Algebra for the Sciences was a better course than College Algebra regardless of one's gender, major, ethnicity, grade point average, grade in the course, age, Math ACT or Composite ACT scores. The same was true for all of the critical thinking subscores with the following two exceptions. Females did better in College Algebra on the Interpretation subscore. Those students who received high grades in the course did better in College Algebra on the Deduction subscore.

Overall, the students made gains in the overall critical thinking score and in four of the subscores indicating that college attendance has a positive influence on critical thinking. However, only the Assumption and Evaluation subscores showed statistically significant gains. The Deduction subscore actually decreased slightly (but not significantly so). As for individual factors that are related to overall critical thinking, the following were found to be significant and are listed in order from the most related to the least related: Composite ACT, grade in the course, Math ACT, grade point average and academic major. The following factors were not found to be related to critical thinking: ethnicity, gender and classification of student (freshman, sophomore, etc.).

Conclusions

Overall, the Algebra for the Sciences course is better than the College Algebra course in terms of improving students' critical thinking skills. The gains made in critical thinking were larger in the Algebra for the Sciences course on the overall score and on four of the five subscores. Although the differences in the gains made in the two courses were not statistically significant, this was probably due more to instructor inexperience in teaching the course than to the content or methods used in the course. It could also be partly due to the fact that the textbook used in the Algebra for the Sciences course was still not fully developed. Since the two courses had the same instructors and covered roughly the same mathematical topics, the larger gains made in the Algebra for the Sciences course might be explained by the interdisciplinary nature of that course.

Although the students in the eight sections of the two courses were never told that they were a part of a research study or that not all of the algebra classes were the same, at least a few of them did figure out that there were differences by the end of the semester. This leads to the possibility of the John Henry effect (which means the students in the comparison group may have tried harder than normal because they felt they were in competition with the experimental group) or maybe the Hawthorne effect (which means the mere fact of being studied and getting extra attention led to the students trying harder than they normally would have). In subsequent semesters, when the instructors have more experience teaching the

Algebra for the Sciences course, stronger conclusions can probably be made about its effect on students' critical thinking abilities.

In addition to studying the students' critical thinking skills, anecdotal evidence was also gathered with regards to the students' mathematical problem solving skills and their attitudes towards mathematics and science in general. Based on common questions on the final exams from the two courses, the two instructors agree that the problem solving skills of the students in the two classes were comparable. They also agree that the attitudes of the students who took the interdisciplinary course were more positive than the attitudes of the students who took the traditional college algebra course.

Disregarding which course was taken, this study is in agreement with the majority of literature in which it was concluded that college attendance has a positive effect on students' critical thinking skills. It is also in agreement with previous studies in which it was concluded that Composite ACT, Math ACT, GPA and academic major are related to critical thinking. It is also in agreement with studies in which it was concluded that ethnicity and gender are not related to the ability to think critically. The results of this study do not seem to support the idea that students with more college credits are better critical thinkers, because in this study classification was not found to be related to critical thinking. That is probably due to the biasness of the sample in this study. That is, juniors and seniors who enroll in a freshmen level mathematics class are not representative of most college juniors and seniors.

Need for Further Studies

There were several questions raised in this study that have no apparent answer. Some of these will need to be addressed in future studies. Among them are:

1. What effect does an interdisciplinary algebra/science course have on students' mathematical and scientific problem solving skills?
2. What effect does an interdisciplinary course have on students' attitudes about the disciplines included in the course?
3. Does the instructor's familiarity with the course influence a student's critical thinking ability, and if so, to what degree?
4. Can the students' gain in critical thinking ability be partly attributed to the particular instructor teaching the course, and if so, to what extent?
5. To what extent does the textbook in a course contribute to the students' critical thinking ability?
6. To what extent does the subject matter in a particular course contribute to the students' critical thinking ability?
7. What other factors, not considered in this study, are related to critical thinking?
8. What other interdisciplinary courses may or may not affect critical thinking?

9. What portion of a student's gain in critical thinking ability can be attributed to natural maturation and not college attendance?

10. Why did the students' Deduction subscore in this particular study decrease for both courses?

If we are to truly understand the concept of critical thinking, these questions as well as many others will have to be answered. Once we know better what critical thinking is, and what factors affect it, then, and only then, can we really concentrate on improving those skills in our students.

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