

INTRODUCTORY COMPUTER PROGRAMMING COURSES USED AS A
CATALYST TO CRITICAL THINKING DEVELOPMENT

A DISSERTATION
SUBMITTED TO THE GRADUATE SCHOOL
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE
DOCTOR OF EDUCATION

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JULY 2011

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Acknowledgements

The last couple of years have been a tremendous challenge for me as I worked on this project. I realize, though, that there are many people who helped me along the way and that without them, this would not have become a reality. I extend my gratitude to Dr. Roy Weaver, who stepped in as my committee chair midstream and helped to re-energize me. His patience, guidance, and unrelenting hard work have been a remarkable asset that has made the completion of this project possible.

I want to thank Dr. Laurie Peters, my supervisor and friend, who pushed me on a daily basis to keep me focused, as well as accommodating my schedule to allow me time to complete this project. Without her constant pushing and motivation, this project would likely have stayed in its infancy. I also wish to thank Amy Smelser, a friend and guide, who poured through every detail of this project, giving valuable feedback along the way, sometimes brutal but always beneficial. Her feedback helped to give me the reassurance that I was on the right track and motivated me to move on.

My husband, Steve, and my daughter, Kortney, have been a tremendous source of support and motivation for me. They never stopped believing in me. Their enduring patience during my stressful times is greatly appreciated. They were there to support me during the times when I was frustrated and never let me give up. You have been the inspiration for me to continue this project.

This project would not be possible without the program chairs in the various campuses that were willing to take time out of their schedule to make this happen for me.

Jill Canine has been a steadfast supporter from the beginning, offering her students for participation in this project. Jill was very patient as the date for data collection kept getting moved. In addition, Paul Addison stepped up to the plate when asked to enlist his students in this project. Matt Hayes, program chair for my region, took over my role as program chair, which meant he became involved in this project just as it was getting underway. Without the support of these program chairs, this project would not have been possible.

Most importantly, I want to give credit to God because it is His grace and mercy that has put me where I am today to allow me to complete this project. I started a journey with God many years ago and His love and support has endured through all of my struggles. To Him I give all the Glory.

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ABSTRACT

DISSERTATION: Introductory Computer Programming Courses as a Catalyst to Critical Thinking Development

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Date: July 2011

Pages: 75

The purpose of this quantitative study was to investigate critical thinking development in an introductory computer programming course in which problem-solving was a key component of the course, compared with another college level computing course in which problem-solving is not a key component. There were two hypotheses in this study. The first was that students would show a greater increase in critical thinking skills after they participate in CINS 113 than CINS 101. The second hypothesis was that students' critical thinking skills at the beginning of CINS 113 would predict the final grade in the course. Prior to conducting the study, approval was received from both institutions' review boards and all guidelines were followed. A control group was recruited from students enrolled in a course that was determined to not have problem-solving as a key component of the course and an experimental group was recruited from students enrolled in an introductory computer programming course. Both courses were from a Midwestern community college. Program chairs from various regions throughout the state volunteered their faculty and students to participate in the study. Students were administered the Cornell Critical Thinking Test on the first day of the semester and again

at the end of the semester. At the end of the semester, faculty submitted final semester grades for all students participating in the program. A comparison of the pretest was made against the posttest using a repeating ANOVA test to see if there was a significant change between the two scores and if there was a difference in the change in scores between the two groups. In addition, the pretest was analyzed against the final grade for the course to determine if a relationship existed between the critical thinking score at the beginning of the course and the student's success in the course. A correlational analysis, as well as regression analysis, was conducted. There were a total of 213 students who completed the study. The results of the study supported both hypotheses.

Chapter 1

Introduction

As an instructor of computer information systems, the issue that repeatedly arises among employers is the need to develop students' soft skills, which include, in part, communication, leadership, and critical thinking. Potential employers place a high priority on critical thinking (Scott, 2000), and as a result, the concept has been a top-rated skill expected of new college graduates for many years (Maricle, 2003). For several decades, the field of computer information systems and its curriculum has been influenced by the demand for critical thinking.

In the early 1980s, undergraduates in universities were commonly required to take a computer programming course precisely because it was believed to develop critical thinking skills. Program logic and design taught students the logical thinking involved in developing computer programs, without any real emphasis on computer program syntax. In other words, it attempted to teach students the logical thinking that computers encounter in decision-making. It provided students with problem scenarios, and they were then to break the problem into smaller, more manageable pieces, and analyze each of those parts to come to a conclusion about the solution to the problem. The process involved a meticulous approach to problem-solving, requiring each and every piece of the process to be analyzed in detail. Students were required to complete this course with the idea that even if they did not intend to be a computer programmer, the problem-solving

process used in this course involved analysis, synthesis and evaluation, and therefore, critical thinking development was likely to occur. In the early 1990s, as computer programming became a popular field of study, the practice of requiring computer programming of all students became less prevalent. Computer programming curricula were growing more and more popular as the field of programming became a vital, independent field of study.

Problem Statement

As noted earlier, it has been assumed for some time that students who took a computer programming course would be more likely to develop higher level critical thinking skills. Yet, as will be shown in the review of literature, there has been little evidence to support or refute this contention. Were educators who required all students to take a computer programming course as a part of their core curriculum correct to assume the course improved their critical thinking skills? This question served as the problem examined in this study.

Purpose Statement

The purpose of this study was to investigate whether students improve their ability to think critically after participating in an introductory computer programming class in which problem-solving is a key element of the course. This study also explored the relationship of critical thinking to the success of students in an introductory computer programming course.

Research Questions and Hypotheses

This study addressed the following questions and hypotheses:

1. Will the critical thinking skills of students who participate in CINS 113, in which problem-solving is a key component, show a greater increase than students enrolled in CINS 101? H1: Students enrolled in CINS 113, in which problem-solving is a key component, will show a greater increase in critical thinking skills than students enrolled in CINS 101.
2. Will students' critical thinking skills at the beginning of CINS 113 predict the final grade of students' at the end of the course? H-2: Pretest scores in critical thinking will show a positive correlation with the final grades of students in the CINS 113.

Significance of the Study

Many institutions of higher education have identified critical thinking as a core competency that they expect students to develop by graduation. Because of this, answers to the questions relating to critical thinking in a computer programming environment could have important implications for higher education in general (Brookfield, 1989; Meng, 2003; Weigel, 2002). As a result of this study, the Midwestern community college may have a better understanding of the implications of the decisions that it makes regarding curriculum development, particularly related to CINS 113. If critical thinking is a goal of this logic and design class, then goals and objectives can be modified that will hopefully further enhance critical thinking development. In addition, decisions about which programs are required to complete this course can be based on knowledge and understanding of the critical thinking benefits derived from it.

Since employers put so much emphasis on critical thinking, it is important to understand how students develop it. Given that this Midwestern community college

supports the assumption that the computer program logic and design course is providing students with improved critical thinking, it is imperative to understand the exact benefits students are receiving it. An understanding of the effects of critical thinking development in the CINS 113 course will enable the curriculum committee to make informed decisions about whether to require it for all computer majors. If critical thinking is not a by-product of the computer program logic and design course, then the curriculum developers for the computer programming curricula may need to rethink requirements for students or possibly redesign the course to improve the critical thinking development aspects.

Definitions

The following terms were important to this study.

Critical Thinking. This study relied heavily on the test instrument, Cornell Critical Thinking Test, Level Z (CCTT), to measure critical thinking. This test defines critical thinking as “reasonable and reflective thinking focused on deciding what to believe or do” (Ennis, Millman and Tomko, 2005, p. 1). Ennis identified “three types of inferences to beliefs (induction, deduction, and value judging) and four types of bases for such inferences, which are: 1) the results of other inferences, 2) observations, 3) statements made by others, and 4) assumptions” (Ennis, et al., 2005, p. 2). Each of these types of inferences involve the process of analyzing the situation (analysis), which uses induction, deduction, and observation, incorporating one’s own beliefs into the situation (synthesis), which uses credibility and assumptions, and then applying an evaluation to the situation (evaluation), which derives meaning and makes conclusions (Ennis, et al., 2005). Therefore, critical thinking even within the context of the CCTT can be defined within the broader scope of analysis, synthesis, and evaluation.

Introductory Computer Classes. CINS 101 (Introduction to Microcomputers):

The course catalog description reads:

Introduces the physical components and operation of microcomputers. Focuses on computer literacy and provides hands-on training in four areas of microcomputer application software: word processing, electronic spreadsheets, and database management and presentation software. Use of a professional business integrated applications package is emphasized (Midwestern community college catalog, Introduction to Microcomputers, 2010, par. 1).

This course description lacks any terminology that suggests analysis, synthesis, or evaluation. It appears as merely a hands-on, student-interactive course that teaches students how to use computer software that is typically used in a business environment. Although it is possible that participation in this course might increase critical thinking skills, there is no aspect of the course that deliberately emphasizes critical thinking. Therefore, it was not anticipated that critical thinking would be a natural by-product of this course. In sum, in this introductory computer course, critical thinking is not emphasized.

CINS 113 (Program Logic and Design): The course catalog description reads:

Introduces the structured techniques necessary for efficient solution of business-related computer programming logic problems and coding solutions into a high-level language. Includes program flowcharting, pseudo coding, and hierarchy charts as a means of solving these problems. The course covers creating file layouts, print charts, program narratives, user documentation, and system flowcharts for business problems. Reviews algorithm development, flowcharting,

input/output techniques, looping, modules, selection structures, file handling, and control breaks. Offers students an opportunity to apply skills in a laboratory environment (Midwestern community college catalog, Program Logic and Design, 2010, par. 2).

This description emphasizes problems and solutions. The emphasis in this course is on how to use the different computer programming tools to analyze a problem and derive a solution to that problem. Different problem scenarios are generated and students are helped to incorporate increasingly more complex tools to develop increased problem-solving skills. This allows students to arrive at a decision that correctly solves the problem, while using precise techniques that are appropriate in the computer programming environment. In sum, in this introductory computing course, critical thinking is emphasized.

Assessments. Two forms of assessment were used in this study:

1. The Cornell Critical Thinking Test, Level Z (CCTT) has been widely used for pre-and posttests to assess critical thinking in college age students and adults. Level Z “contains sections on induction, credibility, prediction and experimental planning, fallacies (especially equivocation), deduction, definition, and assumption identification” (Ennis, et al., 2005, p. 5). CCTT pre- and posttests were used to see if one course had a greater effect than the other on the development of higher levels of critical thinking.
2. Final course grades. Faculty assessments of student performance, recorded on grade sheets, were used to see if there was a relationship between the CCTT pretest and the final grade.

Assumptions

The primary assumption of the study was that students enrolled in a computer programming course, compared to students in a more general introductory computer course, would demonstrate higher levels of critical thinking at the end of their course. A second assumption was that individual faculty teaching sections of the two courses would cover essentially the same material, given that a common syllabus was required. Finally, it was assumed that results from the study would be beneficial to the institutions and faculty participating, for considering revisions to their courses and curricula.

Limitations

Creswell (2002) considered limitations in research to be potential weaknesses in the study or problems the researcher has found with the work being performed. There are many different factors that impact academic performance, such as attendance, completion of assignments, age, region in which the student was enrolled, and gender. This study attempted only to control for region and gender. The manner in which the background information was collected prevented a direct connection of demographics to each individual student. As a result, it was not possible to control for other demographic factors.

The use of a convenience sample was another limitation. Students in the two courses used in the study were selected from classes in which students self-enrolled. One result was that the two groups differed significantly on the basis of several demographic factors – gender, degree of college experience, and majors. In sum, the sample could not be considered randomized (Hinkle, Wiersma, & Jurs, 2003). As Creswell (2002) stated, “because these participants have not been systematically selected, the researcher cannot

say with confidence that they are representative of the population” (p. 167). As such, the results of this study were confined to the population assessed and the institutions from which they were drawn. Although the use of this convenience sample greatly restricted the generalizability of the study, Creswell indicated that studies employing convenience samples do provide the academic arena with valuable data that when compiled with other information broadens the understanding of the selected phenomena.

The assessments and the timing of their administration were also an issue of concern. Although this was likely to be less of a factor for the pretest, the posttest was given at the end of the semester when students were fatigued. They had experienced a long, stressful semester. In many cases, they took the critical thinking assessment after completing the final exam. Students were likely less committed to completing the critical thinking assessment accurately and completely due to their exhaustion.

Although all regions that participated in the study used at least one of the same textbooks throughout, there may have been differences in how the objectives were implemented. As a result, there may have been differences in the emphasis on critical thinking development by faculty who participated in the study. These differences may have had some impact on critical thinking development. Since these differences were not analyzed, potential effects were not measured. Similarly, differences in the way that faculty evaluated student work may have had an impact on grades assigned. This was important because the final grade in the course was a variable studied.

Summary

In this chapter a brief historical overview on the role of critical thinking as a desired outcome in computer programming courses was presented. It was noted that

while critical thinking was assumed to be an outcome, there was little evidence to support this contention. This problem and its significance – lack of evidence – was the primary basis for undertaking this study. Key questions, hypotheses, and terms that provide a framework for the study were outlined. Factors that indicate some caution in considering the results were described.

Without question, critical thinking has been and continues to be a core competency for students graduating from institutions of higher education (Brahler, Quitadamo, & Johnson, 2002; Meng, 2003). The definition of critical thinking, how it is viewed in higher education, and more specifically, in computer programming courses, how it is assessed in relation to student performance, and how it relates to age and gender are examined in the forthcoming review of literature.

Chapter 2

Review of the Literature

Introduction

Chapter 2 provides a review of literature related to the following topics:

(1) various definitions of critical thinking; (2) critical thinking in higher education; (3) critical thinking in computer programming; (4) assessment of critical thinking in higher education; (5) critical thinking and student performance, and (6) critical thinking as it relates to age and gender.

Critical Thinking Definitions

The underlying concept of critical thinking comes from Bloom's (1956) theory of hierarchical thinking, later known as "Bloom's Taxonomy." His theory laid the conceptual framework for understanding learning attainment in three major domains -- cognitive, affective, and psychomotor (Clark, 1999; Krumme, 2001). Of these domains, he was most recognized for developing the cognitive domain to aid teachers, administrators, curriculum developers, and educational researchers in establishing descriptors for student learning. In doing so, he identified six levels of progressively more advanced and complex demonstrations of thought: "knowledge, comprehension, application, analysis, synthesis, and evaluation" (Ennis, 1992, p. 18). The levels most often linked with critical thinking, according to Ennis are the last three: analysis, synthesis and evaluation.

These levels of thinking were studied in detail by a group of cognitive psychologists at the University of Chicago headed by Bloom. The belief by Bloom and his associates was that many of the simple cognitive behaviors could be merged together with other equally simple behaviors, which would result in a more complex behavior. The more complex the behavior, it was argued, the more difficult the cognitive effort needed to accomplish it. As students master and combine simple skills, they may develop some form of critical thinking, even when critical thinking or problem-solving is not a component of their instruction. Over time, the academic community came to support the hierarchical learning taxonomy as a means for representing how students learn to think critically (Clark, 1999; Facione, 1990; Stassen, Doherty & Poe, 2001). As a result, Bloom's taxonomy became the foundation for critical thinking definitions.

Despite this fact, and although critical thinking is widely used in higher education, no specific, universally accepted definition has been found (Courros, 2002; Dult-Batthey, 1997; Tama, 1989). One definition, which closely reflects the components of Bloom's taxonomy, was presented by Scriven and Paul (1987) at the eighth Annual International Conference on Critical Thinking and Education Reform. They defined critical thinking as "a process of intellectual discipline that involves the act of skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information based on observation, experience, reflection, reasoning, or communication" (par. 3). Another definition, offered by Halpern (1996), described critical thinking as "thinking that is purposeful, reasoned and goal directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions" (p. 5). Cornbleth (1985) succinctly characterized critical thinking as informed skepticism without sarcasm.

Others believe that the critical thinker is prone to challenge truth statements and, in general, is more likely to be “discerning in recognizing faulty arguments, hasty generalizations, assertions lacking evidence, truth claims based on unreliable authority, ambiguous or obscure concepts, and so forth” (Burbules & Berk, 1999, p. 2).

Given the array of differing definitions, under the auspices of the American Philosophical Association, Facione (1990) conducted a Delphi study with a panel of 46 experts in critical thinking theory, curriculum, and assessment. These experts attempted to solidify the definition of critical thinking by developing a set of skills and sub-skills that could be used to recognize and identify critical thinking as shown in Table 1.

Table 1

Delphi Study Consensus List of Critical Thinking Cognitive Skills and Sub-skills

Skill	Sub skill
Interpretation	Categorization Decoding Significance Clarifying Meaning
Analysis	Examining Ideas Identifying Arguments Analyzing Arguments
Evaluation	Assessing Claims Assessing Arguments
Inference	Querying Evidence Conjecturing Alternatives Drawing Conclusions
Explanation	Stating Results Justifying Procedures Presenting Arguments
Self-Regulation	Self-Examination Self-Correction

Note. Adapted from “Critical Thinking and Critical Pedagogy: Relations, Differentiation and Limits,” by N. C. Burbules and R. Berk, 1999. In T. S. Popkewitz and L. Fendler (Eds.), *Critical Thinking Theories in Education*. Retrieved from <http://faculty.ed.uiuc.edu/burbules/papers/critical.html>

These skills and subsequent sub-skills became a foundation for development of critical thinking in higher education. While Barnett (1997) pointed out that critical thinking can take on a number of different meanings, the result of the work of the Delphi panel of experts was to bring higher education closer together in agreeing on a definition. At the conclusion of their work, the panel wrote: “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” (Barnett, 1997, p. 3).

As previously mentioned, the process of solving problems, formulating inferences, calculating likelihoods, and making decisions is at the core of critical thinking. The ability to use these skills properly, without prompting, and generally with a purposeful intent in an assortment of different settings, is what makes one a critical thinker. According to Halpern (1996), critical thinking involves evaluating the outcomes of one’s own thought processes, deciding how good a decision is or how well a problem is solved. Critical thinking does not entail looking for fault in something, as the term critical might imply, but instead involves using evaluation or judgment to construct practical and precise feedback that serves to improve the thinking process.

Critical thinking skills often are considered higher order cognitive skills. Rote memory type activities, such as computational arithmetic, do not require higher order thinking skills. Although these skills are important, they do not require any type of analysis based on context or other variables that may determine outcome. Higher order

thinking skills are developed when students are required to think in ways that are reflective, sensitive to the content, and self-monitored (Halpern, 1996).

The epistemology of thinking in general, or the nature of the knowledge concerning how we think about thinking, provides a foundation for investigating critical thinking. Creswell (2003) contended that a “construct is an attribute or characteristic expressed in an abstract, general way” (p. 130). The theoretical construct for this study is based on the proposition that the phenomenon of critical thinking is a more rigorous form of thinking than “good thinking” (Facione, 1998, p. 14), and it can be observed through the manifestation of certain discrete cognitive skills (Fisher, 2003). The top three levels of Bloom’s Taxonomy of learning (1956) provide the theoretical basis for identifying cognitive skills to be examined--analysis, synthesis, and evaluation--and are considered to be the critical thinking levels. These levels of thinking can be described as the discrete cognitive skills referred to above and are considered to be the foundation for critical thinking (Astleitner, 2002; Facione, 1990; Meyers, 1986; Scriven & Paul, 2004).

Critical Thinking in Higher Education

Critical thinking has been identified by a number of leading organizations and accrediting bodies as an important goal for postsecondary education (Association of American Colleges and Universities [AAC&U], 1985; National Education Goals Panel, 1991; National Institute of Education Study Group, 1984). In 2004, leaders of higher education associations and accrediting bodies met to identify a common set of skills for postsecondary education. Along with quantitative and qualitative literacy, information literacy, teamwork, and integration of learning, critical thinking was noted as one of six most important intellectual and practical skills (AAC&U, 2004). As a result of these

efforts, higher education institutions have increasingly been expected to develop graduates capable of using higher order thinking skills in their chosen majors and future careers (AAC&U, 2005; Scott, 2000).

Most institutions, in some fashion or another, feel responsible for helping students becoming better, more independent thinkers (Pithers & Soden, 2000). Scott (2000) pointed out that the importance of critical thinking is evidenced by the fact that most higher education curriculum objectives have some component of critical thinking within the curriculum guidelines and it is often an important piece of the credentialing body's assessment of quality. It is not unusual to see the words analyze, argue, discuss and evaluate within the course objectives, indicating a desire for students to go deeper than the lower level learning of development of knowledge, comprehension and application. As students become more developed in their critical thinking, they become better able to make sound, reasonable decisions about the world around them.

The value of critical thinking as a goal of learning in higher education has been discussed. In a report by the University of Maryland University College Office of Outcomes Assessment (2006), critical thinking was described as an inherent component of effective learning. In order for one to learn, writers of the report indicated, there needs to be an ability to interpret information that is presented to them and for them to make relationships to previous knowledge. Critical thinking skills make this possible. As a result, higher levels of intellectual development that accompany critical thinking skills enable graduates to continue to contribute to society long after the knowledge they gained in the classroom has become obsolete. According to Kitchener and King (1984), it is more likely that for students who go through a college curriculum and graduate, there

will be significantly greater gains in complex reasoning and judgment than for their peers with similar academic preparation who did not attend college. Colletta (2010) supported this point, indicating that a phenomenon occurs within the higher education process that causes students to start to make connections among things that are not at first obvious and to begin to understand the need to look beyond the surface. These processes are usually not planned or “staged” but are naturally occurring events as a direct result of exposure to higher education. In particular, it has been shown that the liberal arts curriculum is more likely to enhance critical thinking than other areas (Dlugos, 2003; Erwin, 2003; Seybert, 2002).

Whether or not critical thinking can be taught has been an ongoing debate. Some scholars believe that critical thinking is derived from mental skills that are taught and learned independent of the subject matter being presented (Anderson & Soden, 2001; Astleitner, 2002; Bellis, 2004; Stoney & Oliver, 1999). This line of thinking sees critical thinking in terms of the process or outcome and is judged based on the students ability to engage in discrete cognitive skills, such as analyzing, assessing the merits of an argument and the ability to alter truth claims based on this analysis (Ennis, 1993; Garrison, Anderson, & Archer, 2004). Part of this belief process holds that critical thinking skills can be learned independent of any specific discipline, and those learned skills transfer to other cognitive domains. Ennis (2000) suggested that critical thinking is thoughtful, logical thinking that helps students make a decision about what to believe and execute. This capacity to choose does not appear constrained to a particular cognitive domain.

Not all scholars accept the idea that critical thinking can be taught. Some scholars believe that critical thinking is a personality trait or disposition that must be cultivated

before the thinker can be truly considered a critical thinker (Brabeck, 1983; Facione, 1998; Meyers, 1986; Paul, 1993). This perspective holds that some people have a higher predisposition to think critically and that this is a trait developed over time through well-structured courses. In this scenario, critical thinkers are viewed as persons who engage in a rational process of assimilating and assessing data as a matter of personal behavior. Some scholars within this framework of thinking believe that students who do not have this predisposition for critical thinking will not develop this skill, despite efforts to generate critical thinking within the higher education environment (Couros, 2002; Taba, 1979). However, there does seem to be some overlap within this perspective and the perspective of those who subscribe to the idea that critical thinking can be learned. Therefore, some scholars believe that although some have a predisposition to critical thinking, and consequently, it might come more naturally, these skills can also be learned by those who do not have this predisposition (Mason, 2000; Paul, 1993).

Critical thinking may be a learned activity, but many scholars don't see it as a continuous state. Many scholars support a perspective in which critical thinking is seen as an episode of cognition. Supporters of this perspective recognize a distinction between critical thinking and rationality and argue that rationality is a dispositional trait of persons, while critical thinking is an episodic activity. Although students can engage in rational thought without thinking critically, they must employ the personality trait of being rational as a basis for thinking critically. Many students learn skills during their higher education experience that they choose not to implement, for whatever reason, during various episodes of their learning environment. Students can think rationally but may choose not to engage in the critical thinking process that has been learned.

Personality plays a role in whether a student implements the critical thinking skills that he has learned and developed (McCarthy, 1992). Therefore, to many, critical thinking is a state that can be turned on and off at select moments in time.

Regardless of the position one takes in regard to the preceding debate, the fact is that there clearly are efforts and a number of approaches to teaching critical thinking in higher education. Yancher and Slife (2008) stated that one technique for developing critical thinking is to help students to critically examine theoretical assumptions and implications and that this should be done within the normal course of instruction. The implementation of this approach involves a question-asking strategy. Several researchers (Carroll, 2001; Gray, 1993; Keeley, Ali, & Gebing, 1998) have supported the idea that a question-asking strategy has value in facilitating critical thinking, partly because it places an emphasis on student experience and reasoning. Yancher and Slife (2008) included five steps for the implementation of a question-asking strategy that include:

1. Providing experiences that facilitate student desire to engage in critical thinking, particularly the examination of theoretical assumptions.
2. Forming a generic set of critical thinking questions that enables students to identify theoretical assumptions and discern their practical implications.
3. Identifying theoretical assumptions of theories being studied, via the critical thinking questions.
4. Identifying the practical implications (e.g., scientific, social, educational, medical, legal, ethical) that follow from the assumptions.

5. Having each student formulate a position on the validity or utility of various theories being studied, in light of the theories' assumptions and implications (p. 85).

This strategy has helped faculty engage students to a deeper level of thought than might occur otherwise.

Kuhn and Pease (2008) discussed a process of teaching critical thinking that involves the development of inquiry skills. They described inquiry development, not as the accumulation of objective facts, but as an enterprise that advanced through the synchronization of evidence with developing theories constructed by human thinkers. Sandoval (2005) stated that this understanding of knowledge synchronization could be fostered within a context of inquiring activities that students themselves conduct.

Understanding the process of teaching critical thinking development, however, expands beyond the development of inquiry skills. According to a model of critical thinking development, the reflective judgment model is a conceptual framework for reflective judgment based on seven distinct assumptions about the process of knowing and how it is acquired. Each successive set of epistemological assumptions is characterized by a more complex and effective form of justification. The seven developmental stages of the reflective judgment model can be summarized into three levels: prereflective (Stages 1-3), quasi-reflective (Stages 4 and 5), and reflective (Stages 6 and 7) thinking. In each of the stages of reasoning development, students increase their critical thinking and reasoning skills, advancing their abilities to reflect on knowledge and their own learning. One key element of the reflective judgment model is the development of the reality that knowledge is uncertain and is based on the composition of

reasonable data collection, actively constructing decisions based on the relevant data currently available. As new data become available, critical thinkers are willing to reevaluate their decisions (King & Kitchener, 2002).

While there has been increasing interest in and emphasis on the development of critical thinking in students in higher education, the results have not been promising. Benton (2011) claimed that higher education is not the vessel of critical thinking that it once was and does not agree that critical thinking occurs automatically as a process of the higher education experience. In fact, Benton believed that factors, such as grade inflation, lack of student preparation, student evaluation of teachers, enrollment minimums, lack of uniform expectations, contingent teaching, and time constraints are all changes that have occurred in higher education over the last few generations that have transformed higher education into an institution of career preparation rather than that of a liberal arts education, with critical thinking a casualty of these changes. Barnes (2005) indicated that higher education institutions are still graduating students in alarming numbers without critical thinking skills. Arum and Roksa (2011) indicated that at least 45% of undergraduate students demonstrated a disappointing lack of improvement in critical thinking, complex reasoning, and writing skills in the first two years of college, and 36% showed no progress in four years. These results show little promise for improvement, according to a report by Kuhn (1991), in which he determined that most of the population could not consistently produce legitimate evidence for their opinions, enter counter arguments, or disprove counter arguments.

Critical Thinking in Computer Programming

Researchers have argued for teaching critical thinking related to specific disciplines and fields of study. Ennis (1990) said that there is variability among disciplines in terms of how critical thinking is used and that in order to fully understand a discipline that one must be able to think critically within the particular contexts, domains, or structures of a subject, a position also supported by Facione (1990) and Halliday (2000).

This argument has emerged in the field of computer programming. The idea that both cognitive ability and personality are strong factors in predicting the success of computer programming students has been discussed. Cegielski and Hall (2006) found that cognitive ability and personality exhibit a predictive relationship with Object-Oriented (OO) programming, as did Evans and Simkin (1989). While there has been disagreement about which of these factors is a stronger indicator, Cegielski and Hall (2006) found that personality was stronger. In contrast, earlier studies indicated that cognitive ability was the stronger factor (Evans & Simkin, 1989). Kolling (1999) sided largely with Cegielski and Hall, by saying that long-term improvements in critical thinking might be more attributable to personality factors, such as self-esteem and self-efficacy.

Problem-solving, not synonymous with, but an important part of critical thinking, clearly is an important component of the computer programming curriculum. Before proceeding with a discussion of the place of problem-solving in this curriculum, a distinction needs to be made between problem-solving and critical thinking. Hedges (1991) described problem-solving as a linear process of evaluation and critical thinking

as an overlying set of abilities that allow the inquirer to properly facilitate each stage of the linear problem-solving process. Steps in problem-solving include:

1. Recognizing a problem situation.
2. Defining the problem.
3. The ability to comprehend, develop, and use concepts and generalizations.
4. Testing hypotheses and gathering data.
5. Revising hypotheses and testing revised or new hypotheses.
6. Forming a conclusion.

In contrast, steps in the critical thinking process, as noted earlier in this chapter include:

1. The ability to identify and formulate problems, as well as the ability to solve them.
2. The ability to recognize and use inductive reasoning, as well as the ability to solve them.
3. The ability to draw reasonable conclusions from information found in various sources, whether written, spoken, tabular, or graphic, and to defend one's conclusions rationally.
4. The ability to comprehend, develop, and use concepts and generalizations.
5. The ability to distinguish between fact and opinion (p. 2).

Clearly, the critical thinking process recognizes the ability to think, whereas the problem-solving process is about following a specific set of steps that lead to thought.

Matlin (1998) noted that computer programming is a problem-solving process because it involves creating a program, comprehending a program, modifying a program, and then debugging the program. Planning is an initial process that relies both on

problem-solving and critical skills. The difference between students who possess these skills, as it relates to programming, has been described in the literature.

Lane and VanLehn (2005) stated that novice computer programmers generally do not plan the logic for their programs before they start the process of writing code. As a result, they often are identifying program goals and corresponding schemas needed to solve the problem while in the process of writing code. Many problems develop when computer programmers attempt to write code without planning, yet most beginning computer programmers lack the ability to effectively plan. Barnes (2005) distinguished between the capabilities of programmers in this regard, reporting that expert problem solvers approach problems using the core computer programming structures that enable them to find solutions, while novice problem solvers are consumed with superficial aspects of the problem without understanding the composition of the program.

Hung (2008) discussed the relationship between problem-solving and computer programming, indicating that computer programming helps to improve higher-order thinking skills because of the debugging process required. This process involves the ability to correct small problems in their computer programs, while also searching and finding a solution to their problem. Ideally, he explained, a heuristics approach should be applied to the course that improves inductive, deductive, metacognitive, and creative thinking. He further stated that the analogy and induction aspects of critical thinking are the most relevant to computer programming skills. He concluded that the problem-solving requirements inherent in computer programming are a natural springboard to critical thinking development.

Assessment of Critical Thinking in Higher Education

There are two basic approaches to measuring skill-level attainment, which tend to be at opposite ends of one other. One approach represents the complex, *psychology-based* instruments designed to examine the traits, intent, and motivation of the critical thinker (Facione, Giancarlo, Facione, & Gainen, 1995), while the other reflects the observed behavior from customized *skills-based* measurements of critical thinking (Stein, Haynes & Unterstein, 2003). How an institution of higher learning measures critical thinking skills and the associated sub-skills tends to depend upon the course, the faculty's objectives, and the definition of critical thinking employed by the institution. In the same fashion that there are differing views on how to define critical thinking, there also are differences in how it ought to be measured (Couros, 2002).

Following are examples of these approaches to assessment that have been used to measure critical thinking in higher education. Stein, et al. (2003) conducted a study that addressed the *skills-based* measurement approach, using a test designed by the Tennessee Technical University called the Computer Adaptive Test (CAT). In an effort to measure critical thinking, they chose not to use the more established California Critical Thinking Skills Test (CCTST) because it did not, in their view, assess the particular skills the faculty considered to be important to their own courses with the exception of certain philosophy, problem-solving, or mathematical logic courses. Therefore, they decided to customize their own critical thinking test. This customized CAT used a stratified random sample, examining skills such as problem-solving, working with diversity, and communication. In order to establish validity for this customized test, 104 students took the CAT, another 104 took the CCTST, and 64 in the sample took both tests. Student

scores on the CAT were compared with both the American College Test (ACT) given at the time of admission and the CCTST. The correlation among the tests was good but not overly high (CAT and ACT, $r = .659$ and CAT and CCTST, $r = .645$).

After establishing the validity of the CAT, Stein, et al. (2003) administered the test in two different social science courses that incorporated a pretest followed 13 weeks later by a posttest. According to the study's findings, the CAT showed that it could be used "to identify courses and pedagogies that promote critical thinking and problem-solving" (p. 10). However, the CAT also showed poor criterion validity in the correlation to the ACT scores. Therefore, the CAT was shown not to be an attractive option for the purposes of this investigation. Notwithstanding the unattractiveness of the CAT, the Stein, et al. study did focus on observable skills that could indicate critical thinking as a learning outcome. This approach to critical thinking reflected the skills-based school of thought (Anderson & Soden, 2001; Astleitner, 2002; Bellis, 2004), which suggests critical thinking skills may be taught as distinct cognitive capabilities.

Using a *psychology-based* instrument approach, Facione, et al. (1995) conducted a study of 587 freshmen at a selective, private, comprehensive institution that had completed the California Critical Thinking Disposition Inventory (CCTDI) to determine its students' disposition to think critically. This study used psychological measurements of student personality attributes in relation to motivations and other cognitive strategies. The CCTDI employed a Likert-type scale of seven factors that gauge various traits of the student from aesthetic sensitivity to intellectual curiosity and value systems. The CCTDI was found to be a useful tool for measuring the students' intellectual engagement as well as their active engagement within their own surroundings. Facione, et al. (1995) viewed

this intellectual engagement and situational awareness as the basis for nurturing the personality trait for critical thinking in students to produce critical thinkers. The emphasis on the thinker's traits or predisposition to think critically as a function of their personality or makeup was the focus of this study.

In a final illustration, Solon (2001) used a pre-post comparison of five control groups, that consisted of a total of 128 students who were administered the CCTST and three experimental groups, that consisted of 96 students who were administered the CCTT. Each of the groups was administered the test to measure changes in critical thinking over the duration of the course. The results showed Cohen *d*'s of 1.1, 1.5, and .62 for the experimental groups. For the five control groups, there were no statistically significant pre-post differences and very small effect sizes. These results provided a foundation to support the use of CCTT to measure changes in critical thinking.

A number of reviews of critical thinking tests used in higher education have been presented in the literature. Spicer and Hanks (1995), for example, examined what they called general thinking tests because the tests measured more than just one or two thinking skills. These researchers contended that critical thinking was not a general ability but a complex set of both general and specific factors and abilities that required multiple measures to effectively capture the cognition being accomplished. While the Spicer and Hanks study approached critical thinking from the perspective of having a trait component, it also indicated that the critical thinker required a certain facility with a cognitive domain as proposed by McPeck (1981). Spicer and Hanks held that all of the tests reviewed, including the CCTDI, which was the only measure of critical thinking predisposition they found, had the same "basic weakness of reducing critical thinking to a

set of responses” (p. 6). To offset what they perceived as a fatal flaw, Spicer and Hanks suggested that critical thinking tests should include specially designed performance tests with specific outcome criteria customized for the domain within which the test is given.

Bers (2007) examined 11 standardized tests of critical thinking most often used in community colleges and described their use at a number of institutions. In an analysis of the use of the Watson-Glaser over five years at Metropolitan Community College (Missouri), using more than 2,000 test results, students scored below desired levels on the subtest pertaining to inference. In an examination of the use of the CCTST at Harold Washington College in Chicago in the fall of 2003 with approximately 1,600 students, it was found that “students scored below the national sample of two-year college students, but not significantly so” (p. 22). For these results and others presented in her study, Bers explained actions taken by institutions to provide support for improving test outcomes.

In analyzing tests considered most appropriate for assessing critical thinking skills the American Philosophical Association (APA) has identified two tests as the only general tests for critical thinking available: the Cornell Critical Thinking Test and the Watson-Glaser Critical Thinking Appraisal (WGCTA) (APA, 2000). The association has indicated that all other tests that measure critical thinking are content specific and are not appropriate for measuring general critical thinking.

Critical Thinking and Student Performance

In this study, the relationship of students’ performance as indicated by the end-of-course grade in introductory computer programming courses to their scores on the Cornell Critical Thinking Test (CCTT) was examined. In reviewing the literature, there

were no studies directly related to the purpose of this research. However, there were three studies in other subject areas that were somewhat related.

In one, by Gadzella, Ginther and Bryant (1997), 63 students in an introductory undergraduate psychology course taught by one faculty member completed the Inventory of Learning Processes (ILP) and WGCTA at the beginning of the course. A discriminant function analysis was used to analyze ten scores on the two tests. Results showed that Deep Processing and Methodical Study (ILP) and Total Critical Thinking (WCGCTA) correctly classified 84.2% of the 38 students who received a grade of A and 68% of the students who received a C.

In a second one, by Jenkins (1998), 96 volunteer subjects from four sections of an auditing course in business over two semesters comprised an experimental group taught by one faculty member. A multiple regression model was applied to the results of three auditing course exams and a comprehensive final exam and was used to assess critical thinking ability, GPA, age, and gender as independent variables. Results showed that critical thinking ability was statistically significant in predicting performance later in the auditing course on the third and final exams.

In a third study, Reed and Hansen (2005) studied the effects of the integration of the Paul (1993) model of critical thinking into a community college U.S. history course. An experimental group of 29 students was exposed to this model, while 23 students in the control group were not. Both groups were administered a Documents Based Questionnaire (DBQ) from an Advanced Placement Test Examination, The Ennis-Weir Critical Thinking Essay Test, the California Critical Thinking Dispositions Inventory (CCTDI), and a History Content Exam. The experimental group scored significantly

higher on the DBQ and the Ennis-Weir. There were no statistical differences between the two groups on the other two assessments.

Critical Thinking and Age and Gender

There are competing views concerning the relationship of age and gender to critical thinking. Piel (2008) argued that the exposure to challenging life experiences creates openness to different viewpoints and a willingness to make reasoned judgments. These experiences come from living life and are therefore more prominent among older adults than their younger counterparts. In contrast, King and Kitchener (2002) claimed that there does not appear to be any significant difference in critical thinking abilities between older adult students and the younger adult. In fact, it appears, they argued, that a more significant predictor of critical thinking is actually the length of time in the educational environment rather than age. In the former study, Piel examined critical thinking development as it related to transactional leadership. It was determined that older students developed stronger critical thinking skills and, as a result, were more likely to develop transactional leadership. In the latter study, King and Kitchener (2002) looked at a reflective judgment model that emphasized the development of complex reasoning. They argued that it is the challenging learning opportunities that people are faced with that result in cognitive development that occurs over time. However, as people are faced with increasingly more challenging situations, they discard previous approaches to problem-solving and develop new, more effective strategies, adjusting their belief systems accordingly. These adjustments leave a person with increased abilities to reflect and judge. However, these challenging learning experiences occur as a result of educational exposure, not from age. People who are not exposed to intellectually

challenging situations throughout life will remain relatively stagnant in critical thinking development throughout their lives. It is clear that critical thinking begins to form around adolescence. People who do not go through educational experiences beyond adolescence are likely to not develop beyond adolescent abilities to think critically and will likely adhere to the same thinking processes throughout life. While researchers continue to debate the relationship between age and critical thinking, the fact is that most studies in the literature have shown age as having no significant difference or no relationship to critical thinking (Cillizza, 1970; Feely, 1975; Facione, 1990; Jenkins, 1998; Rodriguez, 2000; Rudd, Baker & Hoover, 2000; Seybert, 2002).

A number of studies have examined the differences between cultural identity and experiences of males and females and the effects of gender on critical thinking. In comparison to studies of age and critical thinking, the results of studies on gender and critical thinking are more mixed. On the one hand, Rodriguez (2000) and Seybert (2002) found that gender had no predictive value in relation to critical thinking. In the study by Rodriguez (2000), development of critical thinking skills in the nursing practice were explored as they were related to age, gender, degree, career path, years of experience, and personality type. None of these predictors were found to be statistically significant in predicting critical thinking. In the study by Seybert (2002), critical thinking scores were evaluated across several semesters for students in a community college. Although the results of the study showed some improvement in critical thinking skills, these improvements were consistent between both genders. Therefore, there were no gender differences in critical thinking dispositions. On the other hand, studies by Walsh (1996) and Rudd, et al. (2000) found significant differences in gender and critical thinking. In

the study by Walsh, students enrolled in undergraduate courses were studied to determine dispositional differences among several university majors and across gender. The results indicated that females scored higher in open-mindedness and maturity, and males scored higher in analyticity. In the study by Rudd, et al., participants taking the CCTDI were evaluated based on critical thinking disposition. It was found that there were gender differences in critical thinking skills with females demonstrating more critical thinking than males. In fact males scored an average of 288.1, while females scored 297.8 on the CCTDI. This difference was statistically significant. Not only were the overall scores greater for females, there were areas in which females clearly outperformed their male counterparts. There were several different constructs on which participants were evaluated. Although there were no differences in gender in most areas of critical thinking, there were three different constructs on which females scored higher than males: truth seeking, maturity, and open mindedness. The results of studies of critical thinking and gender have not been conclusive. Accordingly, most researchers argue that it is important to continue to examine gender in relationship to critical thinking.

Summary

In this chapter competing views on what critical thinking means, how it is developed, and whether or not it can be taught were examined. Regardless of the position taken in regard to these matters, there is no question that higher education institutions value and promote critical thinking as an important learning outcome. While there are a number of critical thinking tests available, it is clear from the review that the Cornell Critical Thinking Test, the one used in this study, has been considered a reputable one. Studies of factors related to critical thinking have shown generally that age is not

typically important, but that gender is sufficiently inconclusive to warrant further study.

The limited studies found on the relationship between critical thinking and student performance indicated the likelihood that level of critical thinking would be related to end-of-course grades.

Chapter 3

Methods

Chapter three provides a detailed explanation of how the study addressed the questions presented by the researcher. Methods used to examine the development of critical thinking through introductory computer programming courses are discussed. Demographics of participants and how they were selected are described. In addition, instrumentation that was used to examine critical thinking is discussed, along with the steps that were taken to collect, code, and analyze the data.

Participants

Population. Hinkle, et al. (2003) defined a population as “all members of a specified group” (p. 11). These statisticians held that the “distinguishing characteristic of a population is not that it is large, but that all those who meet the definition for membership are included” (p. 12). Accordingly, the population of this study included all students enrolled in CINS 113 (Program Logic and Design) and CINS 101 (Introduction to Microcomputers) from a Midwestern community college with multiple campuses in many regions.

Sample. Participants in the sample were selected based on convenience sampling. In educational research, situations often occur that require the use of intact groups, or those that are already configured which is referred to as “convenience sampling” (Creswell, 2002). Groups that were examined in this study were intact as

determined by the students' membership in a class. A convenience sample was used for this study because examining all community college students enrolled in CINS 113 courses was impractical due to time constraints and faculty availability.

Program chairs of computer information systems from three regions agreed to participate in the study. Originally, four regions agreed to participate in the study, but one region did not follow through and complete the first assessment. The program chairs informed the faculty who teach these courses that they would be included in the study during the 2010 fall semester.

All sections of CINS 113 within the identified regions were included in this study as the experimental group. Students taking the CINS 113 were undergraduates, pursuing associate degrees in Computer Information Systems (CINS) or Computer Information Technology (CINT). Eleven sections of CINS 113 were included in the study, with an average of 12.6 students in each class for a total of 139 participants.

All CINS 101 courses in the participating regions that contained 10 or more students were selected, using a modified form of stratified random sampling as the process involved in selecting from this subgroup of the population until there were comparable numbers of participants from this group and the CINS 113 group (Wright, Noble & Bailer, 2007). This group was the control group. There were six sections of CINS 101 students, with an average of 17.6 students in each class for a total of 146 participants. Students taking CINS 101 included students in CINS or CINT programs and also students outside the major. For example, some students taking the course were majoring in business, human services, and public services. Although students could be

enrolled in both courses at the same time, a review of the records indicated that there were no overlapping students.

A Demographic Questionnaire (Appendix A) was used to obtain descriptive data on the sample. Data included age, race, employment status, educational attainment, and computer experience. This questionnaire was given to the students at the beginning of the semester. The demographics among students varied. A total of 213 participants completed the questionnaire. Forty-six percent (46) of the control group was male, while 82% (93) of the experimental group was male. Fourteen percent (14) of the control group was a minority race (African-American, Hispanic, or Asian-American), while 5.2% (6) of the experimental group was a minority race. Forty-six percent (46) of the control group reported this as their first college course, whereas 25.7% (29) of the experimental group stated this was their first college course. Thirty five percent (35) of participants in the control group reported working full-time, 31% (31) reported working part-time, while 34% (34) reported being unemployed. For the experimental group, 17.7% (20) reported working full-time, 29.2% (33) reported working part-time, while 53.1% (60) reported being unemployed. Because these were undergraduate, community college courses, some of the students fell within the traditional college age. However, because of the nature of community colleges, many of the students were older. The mean age of the control group was 27.2 and the mean age of the experimental group was 28.8. Eleven percent (11) of the control group reported being a first time user of computers, whereas 44% (44) reported having some familiarity with computers prior to taking the course. The remaining 45% (45) reported being very familiar or “expert” at using computers. In contrast, only 3.5% (4) of the experimental group reported being first time computer

users, while 35.4% (40) of the experimental group reported having some familiarity with computers prior to the start of class. The remaining 61.1% (69) of the experimental group reported being either very familiar or expert at computers. These demographics were used for descriptive purposes to provide a basic understanding of the sample group. Table 2 shows the demographic data for the two groups.

Table 2

Demographic Information

	CINS 101 N=113	CINS 113 N= 100
Gender		
Male	93 (82.3%)	46 (46%)
Female	20 (17.7%)	54(54%)
Age	27.2	28.8
Race		
African-American	3 (2.6%)	6 (6%)
Asian-American	1 (0.8%)	1 (1%)
Caucasian American	107 (94.7%)	86 (86%)
Hispanic American	2 (1.8%)	4 (4%)
Other	0	3 (3%)
Education		
High School	29 (25.7%)	46 (46%)
Some College	79 (69.9%)	54 (54%)
Bachelors	4 (3.5%)	0
Masters	1 (0.8%)	0
Employment Status		
Full-time	20 (17.7%)	35 (35%)
Part-time	33 (29.2%)	31 (31%)
Not Employed	60 (53.1%)	34(34%)
Computer Experience		
First Time Computer	4 (3.5%)	11 (11%)
Somewhat Familiar with	40 (35.4%)	44 (44%)
Very Familiar with	67 (59.3%)	40 (40%)
computers		
Expert at computers	2 (1.8%)	5 (5%)

Research Design

This study used the nomothetic approach. It depended upon systematic protocols and techniques generally associated with the quasi-experimental research design (Burrell & Morgan, 1979). The protocols included a pretest and posttest of the sample to identify

any changes in critical thinking skills ability after 16 weeks of coursework in two computer information systems courses.

The Variables Studied

This study had multiple dependent variables depending on the test being measured. For question one, the dependent variables were the students' critical thinking skills as measured by the CCTT as a pretest and posttest. Changes in the dependent variable--critical thinking skills--could indicate that the independent variable--the course that the student was enrolled--had an influence on the dependent variable. The one independent variable for question one was the course in which the student was enrolled, and it fell into two categories: non-computer programming and computer programming. The pretest and posttest assessed changes that may have occurred as a result of the intervention (the course).

For question two, measuring the correlation between two variables, the final grade in the course became dependent on the pretest on the CCTT making the final grade the dependent variable and the pretest the independent variable. The pretest scores were used as a predictor of success in the course in which the participant was enrolled.

Instrumentation

The researcher collected four sets of data. One set was demographic information collected on participants, as noted in the preceding section. A second and third set, that measured critical thinking, came from pre- and posttests using the CCTT, Level Z. Level Z is targeted toward gifted high school students, college students, graduate students, and other adults (Ennis, Millman and Tomko, 2005). A fourth set were instructor grade sheets, reflecting student success in the course.

The Cornell Critical Thinking Test. The CCTT is one of the most popular and widely-used tests of critical thinking, in part because of extensive tests of its reliability and validity. According to Ennis, et al. (2005), the reliability of a test is “the extent it can be depended upon to give the same results repeatedly” (p. 16). The CCTT was tested using the split-half reliability method, which was applied to different populations. According to Welkowitz, et al. (2006), the split-half reliability measures the internal consistency of an instrument. It takes the odd and even scores across every participant and correlates the two sets of scores and then indicates the overall degree to which the scale is measuring only one distinct trait. According to Ennis, et al. (2005) the greatest reliability fell with the higher ability students, indicating that the Z Level version of the test is better suited to more sophisticated students. For the population of community college students in the Midwestern community college in this study (the closest match to this student demographic), the split-half reliability measure was .79, which indicated an index of internal consistency. Therefore, it appeared that the Z level version of the test had a high split-half reliability measure for a Midwestern community college population group, while also showing reasonably high measures of reliability for all groups, ranging from .49 to .87, depending on the population tested.

Validity, as defined by Welkowitz, et al. (2006), is the establishment that the scale used to measure a concept is measuring what we believe it to be measuring. Ennis, et al. (2005) argued that construct validity is actually a combination of criterion and content validity, and therefore, is the most valid measure of validity. A popular critical thinking exam is the Watson Glaser Critical Thinking Appraisal (WGCTA), which was used to measure the construct validity of the CCTT. The WGCTA is recognized in the business

industry as a valid instrument for use in hiring, promotion, development and success planning for management, as well as any job that requires individuals to strategize, assess and reduce risk and improve company performance (Pearson Education, 2009). Given different scenarios and different populations, the range of correlation between Level Z and the WGCTA has high levels of validity, with scores from .71 to .55. Therefore, the CCTT was a reliable, valid and appropriate instrument to use with this community college population.

Instructor Grade Sheets. Instructors provided grade sheets at the end of the semester that supplied the final percentage grade for the semester. Because part of this study measured whether scores on the pretest could successfully predict success in the class, attainment was measured based on the students' final score in the class (which was an overall percentage grade). Because the final grade in the class was representative of a culmination of many different factors, including students' attendance in class, completion of homework assignments, in class labs, or whatever other factors the instructor might include in the final grade, the final grade earned in the class provided a different measure of comprehension of the content than the final exam grade. Since the final exam was not uniform across regions or even across the same region in different sections, the use of a final exam grade was not a viable option for this study. Therefore, the final grade was a better factor to measure success in the class.

Procedures

In April 2010 an email was sent to all CINS program chairs within the Midwestern community college explaining the study and requesting voluntary participation in the study. Only one region responded to this initial email. A follow-up

email was submitted two weeks later again requesting participants. With no additional responses to this email, the researcher recruited the help of the Chancellor of Region 5, who solicited help from two other regions within the college. As part of the communication to the program chairs, the purpose of the study was explained, as well as the role that the instructor played in the research. In addition, instructors were told to decide how to incorporate the pre- and posttests into the course. (See Appendix B for the email communication to program chairs.)

In the process of setting up the study, Institutional Review Board (IRB) approval was obtained from both the Midwestern community college and Ball State University. Basic steps were taken to protect students' identities, as well as their role in the course. When students gave the consent to participate, the signed documents were placed in a sealed envelope. This envelope remained sealed until the end of the semester and all grades were submitted. Therefore, the instructor had no knowledge of which students were participating. This prevented any student from consenting to participate in the study out of a feeling of coercion. At the same time, students were aware that they could withdraw from the study at any time.

The course design for each section of CINS 113 and for CINS 101 was uniform. The faculty teaching each of these courses followed a common set of course objectives and a common textbook, ensuring that all students covered the same content. A requirement for participation in the study was that all courses were delivered in the traditional face-to-face format. It is important to note that in all sections of CINS 113, problem-solving was stressed as a critical component of the course. While faculty had

the freedom to use different styles and methods of teaching, the framework for the respective course curriculum was consistent across all sections.

The CCTT pretest, along with the demographic survey (Appendix A) and the consent form (Appendix C) were given to all participants the week of August 16, 2010. Faculty instructions were provided with test packets. Once students completed the tests, the faculty collected them and returned them to the program chair. The program chair verified that all test packets had been submitted. Then, the program chair provided the completed test packets to the researcher.

The CCTT posttest was administered to all participants during the last two weeks of the semester, December 6 to 17, 2010. The same procedure was followed in this case, as was in the collection of the pretests. In addition, however, the final grade sheets were included along with the completed posttest packets.

In January 2011, data collected were organized for eventual analysis. An Excel spreadsheet was used to record data. Students' names were initially entered and a column was created for each piece of data collected, in the order that it was recorded, for those participants who gave consent. After all of the data were entered, names were replaced with numbers assigned according to the class in which students participated, the region of the institution, and the instructor. For example, students in CINS 101 began with a "1" and CINS 113 participants had a number that started with "2," followed by the number of the region from which they participated in the study, and then each section was assigned a number. For example, a student from the first CINS 113 class in region 5 on the list was assigned the number 205101. Data were entered into The Statistical Package for the Social Sciences[®] (SPSS), which was utilized for data analysis.

Data Analysis. Once all data were collected, SPSS, which is predictive statistical analytic software, was used to examine the data in this study. Scores from the Excel spreadsheet were transferred to the SPSS software as needed.

Hypothesis 1 stated that student critical thinking skills will improve after they participate in a computer programming course in which problem-solving is a key component of the course. By using a repeated-measure ANOVA test, differences between the students' critical thinking skills ability at the beginning of their course of instruction and their critical thinking skills ability at the conclusion of their course of instruction within the same course were examined. Differences in changes were evaluated based on the course (CINS 113 or CINS 101) in which students were enrolled.

Hypothesis 2 stated that pretest scores in critical thinking will show a positive correlation with the final grades of students in the program logic and design course (CINS 113). According to Welkowitz, et al. (2006), when there is a desire to quantify the degree to which a relationship occurs between two variables, and how that relationship can be used to predict the value of one variable based on the value of another, a correlational study is done. For this study, the variable pretest score was evaluated to determine if there was any predictive value in this score to the value of the final score in the class. In other words, did the pretest score predict the final score in the class?

The scores from the pretest and final course grade were analyzed using a Pearson's r test within each of the two groups in the sample. Using the Pearson's r measured the magnitude of the relationship between the critical thinking ability upon entry into the course and the student's success within the course, measured by the student's final grade. This was appropriate given the fact that Pearson's r "is a measure

of the strength of the linear relationship between two variables, both of which are continuous” (Wilson, 2005, p. 502).

Pearson’s r shows a correlation between two variables. If a linear relationship is found to exist between the pretest and the final grade, the analyst can then predict one from another using linear regression. Once that relationship is established, the strength of that relationship can be determined by linear regression (Wilson, 2005).

Summary

Two groups of Midwestern community college students, enrolled in two different beginning computer courses, comprised the sample in this study. Both groups were administered pre- and posttests on the CCTT to compare possible gains on this test of critical thinking based on the course in which they were enrolled. In addition, the initial results on the CCTT were used to predict final course grades. To examine the influence on coursework on the CCTT results, an ANOVA was used to determine differences between the students’ critical thinking skills ability at the beginning of the course and at the end of the course. In order to see if there would be a positive correlation between pretest scores on the CCTT and final grades, a Pearson’s r test was run. Finally, a multiple regression analysis was used to determine the predictability of the final grade based on the pretest score, gender, and region.

Chapter 4

Results

Chapter 4 presents the results of the data collected. Each of the research questions is examined, results noted, and tabular information showing the results provided.

Research Question 1

Will the critical thinking skills of students who participate in CINS 113, in which problem-solving is a key component of the course, show a greater increase than students enrolled in CINS 101? The hypothesis related to this question was: Students enrolled in CINS 113, in which problem-solving is a key component, will show a greater increase in critical thinking skills than students enrolled in CINS 101. A factorial repeated measure ANOVA (RMANOVA) was conducted to determine whether a statistically significant increase occurred over the two exams (pretest and posttest) on the CCTT in the course between CINS 101 and CINS 113. According to Field (2008), sphericity can be assumed if there are less than three variables. Since there were only two levels, sphericity in this case was not a factor.

There were significant main effects of the times of exams and group (course in which the student was enrolled), see Table 3. In addition, as shown in Table 3, there was a significant interaction between group and times of exam. This result indicates that the change over time in mean scores was different for the two courses. An examination of

Table 5, which contains means by time and group, reveals that scores increased by nearly 5 points on average for the CINS 113 group, versus approximately 0.5 for the CINS 101 group (see Table 4).

Table 3

Tests of Within-Subjects Effects

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>	η^2
Exams	81.612	1	81.612	44.474	.000	.175
Group	4038.110	1	4038.110	111.125	.000	.347
Exams * Group	429.529	1	429.529	234.069	.000	.528
Exams * Gender	5.794	1	5.794	3.158	.077	.015
Exams * Region	.008	1	.008	.004	.947	.000
Error(exams)	383.526	209	1.835			

Table 4

Estimates Based on Modified Population Means

exams	<i>M</i>	<i>SE</i>	95% Confidence Interval	
			<i>LL</i>	<i>UL</i>
Pretest	19.279 ^a	.327	18.634	19.924
Posttest	22.562 ^a	.322	21.927	23.196

Note: Based on modified population marginal mean.

A pairwise comparison showing the mean of the exams between groups is shown in Table 5. Group 1 (experimental group) had a mean of 20.809 points for exam 1 and 25.928 points for exam 2, with a difference in means between the two exams of 5.119, whereas Group 2 (control group) had a mean of 16.985 points for exam 1 and 17.512 points for exam 2, with a difference in means between the two exams of 0.527.

Table 5

Pairwise Comparison of Group to Exams

Group	exams	<i>M</i>	<i>SE</i>	95% Confidence Interval	
				<i>LL</i>	<i>UL</i>
CINS	Pretest	21.184	.455	20.288	22.081
113	Posttest	26.036	.446	25.158	26.914
CINS	Pretest	16.793 ^a	.426	15.952	17.633
101	Posttest	17.393 ^a	.418	16.569	18.217

Note: Based on modified population marginal mean.

Research Question 2

Will students' critical thinking skills at the beginning of a computer programming course predict the students' success at the end of the course? The hypothesis related to this question was: H-2: The pretest scores in critical thinking will show a positive correlation with the final success of students in the program logic and design class.

When considering the CINS 113 group, the students' scores on the pretest were positively related to their final grade; in this experimental group, $r(98) = .256, p < .05$. The coefficient of determination was .065, which is the proportion of variability in final grades that can be predicted by the relationship with pretest scores.

When controlling for the region, the students' scores on the pretest showed some relationship to the final grade. For Region 1, the student's scores on the pretest were not significantly related to their final grade, $r(25) = .197, p > .05$. The coefficient of determination was .079. For Region 2, the students' scores on the pretest were marginally significantly related to their final grade, $r(22) = .406, p > .05$. The coefficient of determination was .164. For Region 3, the students' scores on the pretest were marginally significantly related to their final grade, $r(53) = .257, p > .05$. The coefficient of determination was .066.

When controlling for gender, the results also were mixed. For males, the students' scores on the pretest were positively related to their final grade, $r(76) = .281$, $p < .05$. The coefficient of determination was .079. For females, the students' scores on the pretest were not significantly related to their final grade, $r(24) = .136$, $p > .05$. The coefficient of determination was .018.

These data were also analyzed using regression analysis. Figure 1 shows the scatter plot with the fit line based on the final grade predicted by pretest score on CCTT for the experimental group. The scatter plot shows that most of the data fits along a line, which indicates a linear regression. However, clearly there are data points that fit outside the line of linear regression. The predictability was measured using regression analysis. The pretest score was the only significant predictor of final grade in the model. The result indicates that after controlling for region and gender, one's score on the CCTT was significantly positively associated with the final grade in the course; i.e., the higher the CCTT score, the higher the final grade (See Table 6).

Figure 1

Experimental Group Scatterplot for Pretest to Final Grade

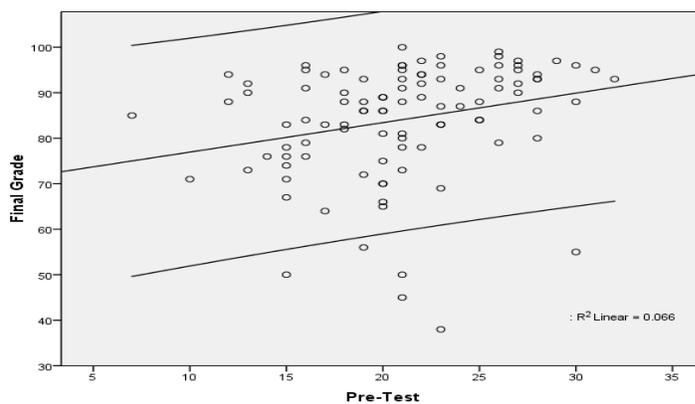


Table 6

Regression Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	SE	β	t	Sig
(Constant)	65.987	6.734		9.799	.000
Pretest	.622	.249	.256	2.495	.015
Region	1.813	1.471	.121	1.232	.221
Gender	.721	2.904	.025	.248	.805

Summary

In this chapter, two hypotheses were examined: (1) that students' critical thinking skills will improve after they participate in an introductory computer programming course in which problem-solving is a key component of the course and (2) that pretest scores in critical thinking will show a positive correlation with the final grades of students in the program logic and design course. In regard to the first hypothesis, a factorial repeated measure ANOVA (RMANOVA) was conducted to determine whether a statistically significant increase occurred between the pretest and posttest of the CCTT completed by students enrolled in CINS 101 and CINS 113. In regard to the second hypotheses, first the correlation between the pretest scores and final student grades was analyzed using Pearson's correlation coefficient. Thereafter, a multiple regression analysis was applied to determine the extent to which certain factors may have accounted for the greatest predictability in the resulting final score on the CCTT. The results of these analyses are discussed in the following chapter.

Chapter 5

Discussion

Findings

Question 1. Will the critical thinking skills of students who participate in CINS 113, in which problem-solving is a key component of the course, show a greater increase than students enrolled in CINS 101? The primary consideration for this study was whether introductory computer programming showed an increase in critical thinking development compared with a course that did not have problem-solving as a key component of the course. The results suggested that the computer programming courses did have an impact on critical thinking scores. How strong an impact the course had on critical thinking is in question, due to multiple factors that influenced course success. Since the control group and experimental group had significantly different demographics, these differences could have influenced the outcome of the study, rather than the actual course intervention. However, efforts to control for two factors, gender and region, determined that these were not factors that impacted the results of this study.

It is not known whether the differences in demographics between the two groups had a significant impact on the results of this study. Was there something about those differences that might have made students more motivated to learn that might not have been related to the intervention of the course? Since the two groups differed so considerably in their level of computer experience, as well as college experience, it is not

known whether it is the experience in computers or college itself that is the difference between these two groups, rather than the intervention of the course. Two noteworthy factors that might influence the study results were analyzed carefully--gender and region. A large difference between the two groups related to gender with 46% of the control group male and 82% of the experimental group male. Both gender and region were controlled as covariates of this study. The results indicated that gender and region were factors that did not have a significant impact on the change in test scores between the pre and posttest. Although all three college regions that participated in this study used a common syllabus with common objectives, the interpretation of the syllabus and objectives varied, as well as implementation. Each region used the same primary textbook but determined their own selection of supplemental textbooks, and then respective faculty determined their own methodology to satisfy the course objectives, from the textbooks selected. This posed a potential influence on the outcome of the study, since not all courses were delivered in the same manner. Therefore, the region in which the course was taken did not have a significant impact on the outcome of this study as related to Hypothesis 1.

These findings can be further understood by looking at the mean scores of the tests between the different groups. Overall, the mean scores between the two tests varied by 3.14 points. The difference in the mean scores for the experimental group was 4.87 points, while the control group had a difference in scores of only 0.54 points. Students in CINS 113, the experimental group, showed a nearly 5-point gain in critical thinking points, compared with CINS 101, the control group that only showed a gain of less than one point.

Region 2 showed a 5-point gain in test scores between the two tests, while Regions 1 and 3 showed slightly less improvement with 2.73 points and 2.58 points respectively. This suggests that Region 2 was slightly more successful in increasing critical thinking overall, but this difference did not indicate a statistically significant difference. It is also important to note that Region 2 did not have any participants in group 2, so it is unknown whether the increased critical thinking scores within that region were specifically related to the experimental group or whether the control group would have also seen those increases. If Region 2 had returned the results from the experimental group participants, it is unknown whether these results would have altered the final results of the study.

The difference in the mean scores for gender was 3.42 points for males and 2.85 points for females. Although males saw a slightly greater improvement in their critical thinking scores, these differences were not statistically significant. As a result, it is not likely the difference in the gender between the control and experimental groups had an effect on the outcome of this study. Many factors influenced the success that students had in a course. The students' study habits, attendance in the course, motivation, to name a few, were factors that might have had an impact on the outcome, but the results show that region and gender were not factors.

There was a significant interaction between the courses and the time of test. This suggests that the computer programming course may have critical thinking benefits that extend beyond what might occur in mere participation in the college experience. Colletta (2010) and Kitchener and King (1984) suggested that critical thinking occurs as a result of participation in higher education. The results of this study suggest that if the college

experience itself, as represented by the control group, contributes to critical thinking, computer programming courses have an even greater impact on the critical thinking scores. King and Kitchener (2002) suggested that as people encounter ever-increasing levels of complexity of problems, they discard old problem-solving techniques for more effective problem-solving, which, in turn, results in more advanced critical thinking. Hung (2008) suggested that the problem-solving involved in computer programming contributed to higher-order thinking skills development. The results of this study support the idea that students in computer programming courses may be more likely to experience an increase in critical thinking development. The notion supported by many scholars that liberal arts courses may likely enhance critical thinking more than other areas was not tested in this study, since the non-programming course is not considered a liberal arts course (Dlugos, 2003; Erwin, 2003; Seybert, 2002).

Question 2. Will students' critical thinking skills at the beginning of the course predict the final grade of students' at the end of the course? It was anticipated that students with higher critical thinking skills who participated in CINS 113 would more likely be successful in the course, and the study findings support this prediction. There was a statistically significant positive correlation between the pretest score and the final grade in the class. The findings of this study from the Pearson's r results suggest that critical thinking scores are related to students' success in the course as measured by the final grade in the course.

The regression analysis also supported these findings. Using regression analysis to analyze the pretest score to the final grade, the pretest score predicted the final grade in the experimental group. Research by Gadzella, et al. (1997), Jenkins (1998) and Reed

and Hansen (2005) suggested that critical thinking scores serve as a predictor for student success and the findings of this study support this point. Cegielski and Hall (2006) and Evans and Simkin (1989) found that critical thinking ability, as well as personality, has a predictive relationship with Object-Oriented Programming. The findings of this study suggest that about 7% of the final grade was explained by the critical thinking score received on the pretest. Although the relationship between pretest score and final grade was not strong, it was significant and thus pretest can be used to predict final grade, albeit with some care.

Gender and region were not significant predictors of the final grade, which suggests that gender and region were not factors significantly impacting the outcome of this study. This finding is supported by Rodriguez (2000), who stated that gender had no predictive value in relation to critical thinking. The findings from the Rodriguez study suggested that the level of critical thinking that a person has entering a course does have an influence on the success that the student will have in it, but many other factors also impact the final grade. Gender and region, however, were not factors in this study. According to Welkowitz, et al. (2006), this requires that region and gender be dropped from the equation.

The results of this study reflected those of prior studies in that critical thinking did show a positive relationship to the final grade in CINS 113. However, it should be stressed that many other factors, in addition to critical thinking skills, had an impact on the final grade. In fact, 93% of the grade was actually impacted by factors other than critical thinking scores. As noted earlier, gender and region were not factors. Examining

the correlation and regression analysis results together suggests that CINS 113, which requires more critical thinking, may result in more mature critical thinking development.

Will this more mature critical thinking improve students' success in other college courses? If so, then it would benefit students to take CINS 113 earlier in their college experience. However, this study suggests that students are more likely to be successful in this course if they have a strong critical thinking background prior to entering it. Since King and Kitchener (2004) and Colletta (2010) have suggested that participation in college courses itself improves critical thinking, it is likely that if students delay participation in CINS 113 until they have more extensive college experience, they may be even more successful.

Recommendations

Future research should examine computer programming students as they progress through the different stages of computer programming to see if the benefits of critical thinking development are stymied at later stages of the process or if development continues throughout the computer programming curriculum. Because this study found that CINS 113 acted as a catalyst to enhanced critical thinking development, it is possible that this development would continue throughout the computer programming curriculum. However, it is also possible that the benefits early on in the computer programming curriculum are not continued as students' progress, but that this initial improvement in critical thinking development prepares students to be successful in the more advanced computer programming courses.

The control group consisted of students from many different majors, whereas the experimental group contained students specifically entering the field of computers. Is it

possible that those entering the field of computers are different in their critical thinking skills than those exploring other fields of study? This indeed may have been a factor in the results that should be explored further in other studies.

Because there were some students majoring in Computer Information Systems (CINS) and others majoring in Computer Information Technology (CINT) taking the CINS 113, it would be useful to determine if there was a significant difference between these majors in their critical thinking development. Do students who already have an interest in computer programming get more benefit from CINS 113, in regard to critical thinking development, than those who may have less interest in computer programming? If students have an interest in computer programming as a major of study, then it is reasonable to assume that they will put more effort into CINS 113 than someone who has less interest. Therefore, it would be interesting to find out if that interest contributed to the success of students' critical thinking development. As many of the CINS students have selected computer programming as their chosen careers, it is also a possibility that students who choose computer programming as a major are significantly different in their critical thinking development and that it is this difference that draws them to the computer programming field in the first place.

Since there was no effort to control for the delivery methods of the faculty and the degree of critical thinking development activities within the course, it would be beneficial to study this issue in a more controlled environment in which the curriculum for all participants is pre-determined, monitored, and controlled. Perhaps repeating this study with online students would be beneficial, since the online version is standardized

throughout the Midwestern community college and would provide a more consistent delivery methodology.

Because both groups that participated in this study were enrolled in computer courses, it would be useful to repeat the study using courses that are non-computer courses to find out if the use of computers is a contributing factor to critical thinking development. It is possible that it is not the overall college experience that explains the critical thinking development among the participants in the control group but the use of computers within both courses. It perhaps would be beneficial to conduct a study in which general studies courses in which critical thinking is emphasized are used as the control group. It would be useful to see if CINS 113 is unique in its critical thinking development as opposed to liberal arts courses. Selecting participants from a variety of courses across the disciplines and fields of study as the control group, without regard to the extent to which these courses include aspects of critical thinking in their content, might also provide valuable information about the uniqueness of CINS 113.

Since critical thinking is such a vital aspect of the college experience, according to numerous leading organizations and scholars (Association of American Colleges and Universities [AAC&U], 1985; National Education Goals Panel, 1991; National Institute of Education Study Group, 1984; Pithers and Soden, 2000; Scott, 2000), it would likely be beneficial for faculty to be provided professional development in the area of critical thinking and the specific techniques for the development of critical thought. In addition, it would be beneficial that the curriculum committee for all programs within the Midwestern community college, but particularly the CINS and CINT programs, review

the course objectives within the course syllabi to ensure that critical thinking is purposefully included as an outcome of the course curriculum.

Conclusions

The results of this study showed that CINS 113 does develop critical thinking skills at some level. Therefore, based on the findings of this study, Hypothesis 1 was supported. It is important to note that there were many factors that contributed to the development of critical thinking. Some were not examined, such as: differences in college experience, computer experience, major field of study, and ethnic group. Gender and region were examined, but were found to have no significant effect on critical thinking development.

The data from this study also supported Hypothesis 2, establishing a relationship between critical thinking scores and student success in CINS 113. It further established that the critical thinking scores could predict the final grade in the course, although caution should be used. Therefore, the stronger the critical thinking skills entering CINS 113, the more likely the student will be successful in the course. This would suggest that if critical thinking is a by-product of the college experience, as suggested by Colletta (2010) and King and Kitchener (2004), then delaying enrollment in CINS 113 until students have had more college experience might allow them to develop more mature critical thinking, which would likely improve a student's success CINS 113.

Consequently, the data suggest a cyclical process to critical thinking development as it relates to CINS 113. The stronger students' critical thinking skills, the more successful they will likely be in CINS 113, while participation in CINS 113 will likely improves their critical thinking skills. Therefore, the curriculum committee for the CINS

and CINT programs might consider delaying entry into CINS 113 for students in programs in which CINS 113 is not a prerequisite. By delaying this course until later in the program curriculum, it is possible that increased college exposure would improve students' critical thinking skills upon entry into CINS 113, which in turn would improve the student's success in the course. Since it appears that CINS 113 does have an impact on critical thinking development, the decision of the CINT curriculum committee to maintain CINS 113 in the curriculum for all computer students, even those who had no interest in computer programming, seems justified simply for the critical thinking benefits.

Summary

In this chapter the results of introductory computer programming on critical thinking development were discussed. Clearly, more research is needed to make any definitive determinations. However, the data suggested a link between critical thinking development and CINS 113, as well as a correlation between a student's critical thinking skills upon entering CINS 113 and their success in the course. Undoubtedly, many other factors contribute to a student's success in any course; in fact, in this study 93% of a student's grade is determined by factors other than critical thinking. It is those factors that need to be studied in relationship to critical thinking development and student success to better understand critical thinking's role in CINS 113.

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Appendix A

Demographic Survey

CRITICAL THINKING THROUGH INTRODUCTORY COMPUTER
PROGRAMMING DEMOGRAPHIC SURVEY

CLASS	DATE	NAME
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PURPOSE:

The purpose of this questionnaire is to help the researcher determine the overall characteristics of the people within the study. Questions raised in this survey will not be used for any purpose other than to help characterize the general make-up of students participating in the educational formats being examined. Also, all links to student names, records, or other identifying documents will be maintained in the strictest of confidence. At the conclusion of this study, all identifying links to students and identifying information will be destroyed.

SURVEY COMPLETION:

Please read all questions completely before answering. When answering, please mark only those answers that apply to you. In every instance you will be asked to mark an "X" by the appropriate answer. Please make your mark clearly. Thank you for your participation.

SURVEY QUESTIONS:

1. Enter your gender.

a. Male

b. Female

2. Please write your age in the box provided.

3. Please select the racial/ethnic category that best represents you. Please select only one.

a. African-American b. Asian-American c. Caucasian-American

d. Hispanic-American e. Pacific Islander f. Other

4. Which category best represents your highest level of education to date? Please choose only one.

a. High school b. Some college c. Associate's degree

d. Bachelor's degree e. Master's degree f. Doctorate

5. Please select the one category that best represents your present work status.

a. Full-time employee b. Half-time employee (more than 20 but less than 35)

c. Part-time employee (less than 20 hours) d. Not employed

6. Which one category best represents your experience with computers?

a. Beginner b. Somewhat familiar

c. Very familiar d. Expert

Appendix B

Email to Program Chairs

Greetings CINS program chairs:

Many of you know me. For those of you who don't, let me introduce myself. My name is Tonya Pierce and I am an Assistant Professor in the CINS program in Region 5, Kokomo. I am currently working on my doctorate degree in Adult Higher and Community Education at Ball State University and am working on completion of my dissertation, which involves critical thinking development in the CINS 113 course. In order to make this study possible, I need the help of a few regions who would be willing to participate in the study. Participation would involve the following:

1. Agree to include students in the CINS 101 and CINS 113 courses in the study.
2. Administer a critical thinking pretest on the first day of class.
3. Administer a critical thinking posttest on the last day of class.
4. Include the completion of these tests as a requirement for the course, in whatever manner is decided by the instructor.
5. Provide a copy of the final exam score and final grade in the class as a percentage score for each class.
6. Submit all tests and documents to me immediately after completion.

The success of this project is dependent on the willingness of you to participate. This study is not possible without your help. The results of this study will allow us to better understand if critical thinking development is occurring within this very important course in our program. A summary of the results will be provided to all regions that choose to

participate in the study. Hopefully, the results of this study can be used to make curriculum decisions for the future.

If you are willing to participate in this important study, please reply to this email, and provide a mailing address and contact person. I will be happy to provide any additional information that you might have concerning any procedures.

Appendix C

Student Consent Form

As a student in this course, I understand that I will be participating in a research study on critical thinking development and that participation in this study is optional. I further understand that choosing to opt out of the study does not exempt me from completing the critical thinking assessments. However, if I choose to opt out of the study, all data from my involvement will be removed prior to analysis of the data. Further, I understand that the instructor will have no knowledge of whether or not I am participating in this study, and therefore, choosing to opt out of the study will not negatively impact my grade in this course. In addition, I understand that all identifying information about my identity will be known only to the researcher and will be removed from all data analysis materials.

Choose one of the following:

I agree to participate in this study and give permission for the results of my assessment to be used in the data analysis for this study.

I do not wish to participate in this study and request that the results of my assessment be removed prior to data analysis.

Student/Participant

Date