DO WOMEN SCORE LOWER THAN MEN ON COMPUTER ENGINEERING EXAMINATIONS?

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THESIS

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ABSTRACT

Women have long been underrepresented in undergraduate engineering programs because they may lack self-confidence and prior experience with technology. Women may drop out of engineering programs when they become discouraged by low exam scores. In this project, we examine whether women earn lower exam scores than men, and whether Dweck's model of self-theories explains the difference.

Dweck proposed two categories for individuals' beliefs about intelligence: incremental theories and entity theories. Incremental theorists believe that intelligence improves with learning, and entity theorists believe intelligence cannot be changed. In many research studies, Dweck found that when entity theorists are faced with difficult problems, they blame themselves for lack of intelligence, whereas incremental theorists think that difficult problems can be solved with more knowledge or effort. Dweck found that women are more likely to be entity theorists than men.

We administered a survey based on Dweck's model in three required undergraduate computer engineering courses at the University of Illinois at Urbana-Champaign. The survey collected each student's gender, ACT or SAT math score, and experience with computers prior to college. The survey included Dweck's instruments to classify students as incremental theorists or entity theorists.

We applied the *t* test and the Mann-Whitney *U* test to determine the statistical significance of differences in exam scores between subpopulations. For all exams in all courses, the differences between exam averages of women and men were not statistically significant. On the first exam and the final exam in one course, entity theorists performed significantly better than incremental theorists. For all other exams, there were no significant differences between exam averages of entity theorists and incremental theorists.

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CHAPTER 1
INTRODUCTION

1.1 Women in Engineering and Computer Science

In the United States, women have always been underrepresented in engineering and computer science. According to the National Science Foundation [1], the total number of bachelor's degrees awarded in 1966 was 524 008. Among those awarded, 146 women and 35 680 men received a degree in engineering. Thus in 1966, women earned 0.41% of all bachelor's degrees in engineering. In 2001, the total number of bachelor's degrees awarded was 1 257 648. Among those awarded, 11 914 women and 47 344 men received a degree in engineering. Thus in 2001, women earned 20.11% of all bachelor's degrees in engineering. Although the difference between the percentages of women and men graduating with an engineering degree had decreased by 2001, women were still underrepresented compared with men.

The percentage of women in engineering and computer science has remained low despite the increased participation of women in the work force. Fullerton [2] states in 1950, labor force participation for people over 16 years of age was 86.4% for men and 33.9% for women. By 1998, the percentage for women had risen to 59.8%, and the percentage for men had declined to 74.9%. If the percentage of women in the workforce increased and the percentage of men decreased, why is the percentage of women in the engineering and computer science professions still low? According to Wootton [3], women and men concentrate in different occupations: "Women are highly overrepresented in clerical and service occupations, for example, while men are disproportionately employed in craft, operator, and laborer jobs" (p. 15). Wootton showed that 93% of registered nurses and 84% of elementary school teachers employed in 1995 were women, compared with 3% of computer systems analysts and scientists and fewer than 10% engineers. In addition, Wootton also noted women made disproportionate gains in managerial professions from 1985 to 1995, while men made disproportionate gains in computer programming. Among purchasing managers, the percentage of women rose from 24.4% in 1985 to 41.5% in 1995. Among computer programmers, the percentage of men rose from 65.7% in 1985 to 70.5% in 1995.

1.2 Why Study the Representation of Women in Engineering and Computer Science?

Why is the underrepresentation of women in engineering and computer science a problem? Why does the National Science Foundation believe the problem is important enough to invest millions of dollars in the effort to increase the number of women in engineering and computer science? According to Cohoon [4], there are two important reasons to increase the number of women. First, when more women enroll in engineering and computer science, they help maintain a pool of high–quality students, populate the profession, and teach future computer scientists. Second, more women in engineering and computer science can provide more diverse viewpoints.

1.3 The Scholarship of Teaching and Learning

The scholarship of teaching and learning (SoTL) is the scholarly study of the relationship between teaching and learning. SoTL has three central features: "being public, open to critique and evaluation, and in a form that others can build on" [5, p. 13].

When a problem arises in teaching, instructors often only want to solve the problem. However, in SoTL projects, teachers investigate the problems rather than simply solving them. When Bass [6] encountered a teaching problem, he started a SoTL project. Bass's problem began when his teaching evaluations plummeted after he introduced experimental "electronic literacy" components into his courses. Bass formulated several questions to direct his investigation. He examined the numbers of students achieving all of the goals, some of the goals, or only a few of the goals. He questioned whether the time spent on each goal was proportionate to its importance. To help answer his questions, he gave students three historical artifacts as examples of what they might analyze in class and asked the students questions about them. He discovered that students assume they lack knowledge rather than skills to analyze the artifacts. Bass's project enabled him to understand students' assumptions and how they learn. He modified his pedagogical methods from his findings to emphasize the skills and ideas he wanted his students to acquire.

It is important to distinguish between scholarly teaching and scholarship of teaching. According to Shulman [7], scholarly teaching "reflects a thoughtful selection and integration of ideas and examples, and well-designed strategies of course design, development, transmission, interaction and assessment" (p. 50). Studies of teaching become scholarship when work "becomes public, peer-reviewed and critiqued, and exchanged with other members of professional communities so they, in turn, can build on our work" [7, p. 50].

Why is the scholarship of teaching and learning important? According to Shulman [7],

> there are three broad rationales for advocating a serious investment in the scholarship of teaching and learning: Professionalism, Pragmatism, and Policy. Professionalism refers to the inherent obligations and opportunities associated with becoming a professional scholar/educator, and especially with the responsibilities to one's discipline symbolized by the PhD. Pragmatism refers to the activities needed to ensure that one's work as an educator is constantly improving and meeting its objectives and its responsibilities to students. Policy refers to the capacity to respond to the legitimate questions of legislatures, boards and the increasingly robust demands of a developing market for higher education. (p. 49)

A SoTL project provides the knowledge that teachers can use to choose pedagogical methods intelligently. Like traditional forms of research, the results of SoTL projects can be shared with colleagues who can build on these results to investigate their own teaching practices.

1.4 Overview of Thesis

According to Bass [6], "in scholarship and researching, having a problem is at the heart of the investigative process; it is the compound of the generative questions around which all creative and productive activity revolves." In teaching, a problem needs to be solved. However, in scholarship and research, a problem initiates an investigation. In our research project, the problem at the heart of the investigation is the underrepresentation of women.

We hypothesize that women leave engineering and computer science because they struggle through courses. We assume that the degree of struggle is directly related to performance on exams. In this research project, we study exam scores of men and women in three different engineering courses.

The motivation for this project came from several initial observations. As a teaching assistant for a computer engineering course, I noticed that women often required more assistance, women had more trouble understanding explanations, and women scored lower on exams than men. I assumed that since women struggle more than men and score lower on exams, they become discouraged and thus leave engineering and computer science. In addition to my own observations, a study conducted by an assistant dean of engineering at the University of Illinois at Urbana-Champaign suggested that women in engineering disciplines receive lower grades than men in core courses in their first two years of study. These core courses include courses in mathematics, chemistry, physics, and engineering courses in their respective disciplines. This study was conducted on incoming freshmen who enrolled between the years 1993 and 1997. Grades of 1000 women and 4500 men were used in this study.

In Chapter 2, I review previous research literature on women in engineering and computer science. In Chapter 3, I describe the methods we used to conduct our research project. In Chapter 4, I present our findings. In Chapter 5, I discuss our results and some possible future work.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Factors that Influence Women's Underrepresentation

Numerous research projects have been conducted to determine the causes for the underrepresentation of women in engineering and computer science. These research projects have inferred eight causes: the gap in experience, lack of encouragement, lack of recognition, lack of peer support and role models, stereotype threat, lack of confidence, attitudes toward performance, and the lack of prestige for applications of technology. These causes are consistent across different demographics, pedagogical methods, and environments. The causes are discussed in depth in the following paragraphs.

2.1.1 The experience gap

The experience gap is the difference between men and women in their prior experiences with technologies. Margolis and Fisher [8] found that at home, young men are more likely to receive computers as gifts than young women. Furthermore, young men are more often taught how to program and assemble a computer. Consequently, upon entering college, more men have had more direct experiences with computers than have women. According to Margolis and Fisher, this difference contributes to the underrepresentation of women in engineering and computer science. In contrast, Liu and Blanc [9] argued that underrepresentation is caused not by lack of experience with computer use but by lack of knowledge about computer terminology and lack of programming experience.

2.1.2 Lack of encouragement

According to Beyer et al. [10], women are more influenced in their course-taking patterns by teachers and counselors than men are. If young women are encouraged by high school teachers and counselors to pursue engineering and computer science, their representation can increase. However, Margolis and Fisher [8] found that in middle school and high school, young women are less often encouraged to pursue the study of computers than young men.

2.1.3 Lack of recognition

According to Klawe and Leveson [11], "Women earn less than men in every field of science, including computer science, regardless of degree or experience level" (p. 31). Furthermore, Klawe and Leveson found that as experience increases, the salary gap widens. That women earn less with the same position, experiences, and skills is an indication of lack of recognition. This lack of recognition in engineering and computer science causes some women to choose fields with equal or better recognition for women.

2.1.4 Lack of peer support and role models

Cohoon [4] reported that some women are more comfortable receiving peer support from other women. Baum [12] claimed that the lack of role models discourages women from considering engineering as a major. Peer support from other women and role models are hard to find in engineering and computer science because the percentage of women is small. Increasing the number of women in engineering and computer science will increase the number of role models and the opportunities for peer support.

2.1.5 Stereotype threat

A minority student experiences "stereotype threat" when the student fears that a negative stereotype about the student's race or gender would become true. For example, one negative stereotype threat suggests that African American students who enter college with equivalent test scores receive lower grades than White college students. Aronson et al. [13] discovered that African American students were less vulnerable to stereotype threat when they were encouraged to treat intelligence as something that can be increased.

The stereotypical computer engineer lacks social graces, spends long hours in front of the computer, and regards programming as a hobby [8]. Women do not want to be associated with these negative stereotypes because they value a balanced life [8].

2.1.6 Lack of confidence

According to Scragg and Smith [14] and Beyer et al. [10], men are significantly more confident than women in using computers in introductory courses. This difference in confidence is caused by the experience gap [8]. Because young men have more experiences with computers than young women do while growing up, they are more confident using computers in college. Because of the experience gap, women who are less familiar with computers often complete assignments with greater difficulty. Often, the obstacles to completing assignments can diminish the confidence of women. Since men can complete assignments with greater ease, their confidence is less often affected.

2.1.7 Attitudes toward academic performance

According to Felder et al. [15], women who have failed one chemical engineering course transfer out of the major at a substantially higher percentage than do men. Felder et al. also found that women with good academic standing are more likely than men to transfer out of chemical engineering. It is possible that women's attitudes toward performance differ from men's. When women struggle with academic tasks, they lose confidence in their abilities, even if their grades suggest otherwise.

2.1.8 The lack of prestige for applications of technology

According to several different researchers [8], [9], [16], women prefer to apply technologies to real-world problems to benefit people. They enjoy applying academic knowledge to social problems such as improving car safety, creating better hospital equipment, and creating educational programs to help children learn [8]. Thus, the applications of computers interest women more than theoretical computing studies. Unfortunately for women, people working on the application of engineering and computer science receive less respect than those working on theoretical studies within academia. The lack of respect for the application of engineering and computer science can lead women to switch majors [8].

2.2 Chilly Climate

Women often feel unwelcome in engineering classrooms and laboratories. According to Kiesler et al. [17], in one preschool, boys created a computer club and refused to allow girls to join the club or use the computers. When teachers intervened to allow girls the same access to computers as boys, girls spent as much time on the computers as boys.

According to Wasburn [18], there are several ways to make women feel welcome in engineering and computer science classes. First, instructors should discuss gender stereotypes and their effect on classroom dynamics. Second, instructors should allow students time to think about the answers to a question before calling on the student whose hand was raised first because women worry about answering a question incorrectly in class more than men. Third, instructors should use examples that both men and women can appreciate. Fourth, instructors should relate course material to real-world applications because women are more interested in working on real-world applications than studying theory of computing. Fifth, instructors should choose a textbook which contains illustrations of women professionals because women need role models, especially in a nontraditional discipline. Sixth, instructors should assign team projects when there is a small number of women in a class; if students choose their own team members, women are usually the last ones to get picked. Seventh, instructors should rotate the tasks of each team assignment so women are not assigned administrative tasks every assignment.

2.3 Interventions

According to Ambrose et al. [19], "If [a young woman] has no parents or close relatives who are engineers, a young woman's initial consideration of engineering occurs often due to suggestions by teachers. At that juncture, her preparation in mathematics and science is important. But what is more vital is how she perceives her capabilities in this respect" (p. 7). But perceived capabilities are hard to sustain when, according to Baum [12], young women start lagging in math and science starting at age nine. If young women's perceptions of their capabilities are low, then not only will the number of women who enter engineering and computer science remain low, but the retention rate of women will remain low as well. Because many of the causes in Section 2.1 affect women prior to their college years, efforts to increase the number of women in engineering and computer science should start as early as middle school and high school.

2.3.1 Precollege intervention

Many specialized programs have been created to help middle school and high school girls learn to program a computer and to inform them about the opportunities an engineering or computer science degree provides. For example, Alice [20] is a computer program that aids middle school and high school students in learning about programming in a fun and interactive way. Alice eliminates mechanical barriers such as syntax rules that can prevent students from successfully learning to write a computer program. Instead, students can drag-and-drop words to manipulate their computer objects. Alice is especially appealing to girls because it supports storytelling, a motivating activity for middle school girls. Other programs such as a week-long Computer Science Seminar at the University of Waterloo for girls in grades 9 and 10 "consists of lectures, labs and activities chosen to demonstrate the breadth of CS and to dispel the negative stereotypes" [16, p. 322].

2.3.2 College intervention

At the college level, there are programs to help recruit and retain female undergraduate engineers and computer scientists. Many universities currently have either a Women in Science and Engineering program or a Women in Engineering program. These programs aim to help women in engineering and computer science. For example, the Women in Science and Engineering program at Arizona State University focuses on five objectives:

> (1) Increase the number of women in the College of Engineering and Applied Science (CEAS), and increase the visibility and networking of female students already in the CEAS; (2) Help students make early connections between majors and potential careers; (3) Educate faculty and advisors about the needs of female students and the importance of their participation in engineering; (4) Help students develop study and time management skills; and (5) Offer programs directed at students' reported needs. [21, p. 771]

In addition to specialized programs, faculty members can also help retain women. Faculty members should encourage women to persist through engineering and computer science courses. According to Cohoon [4], faculty encouragement helps retain women at the rate that men are retained. According to Myers [22], faculty members can help by making an effort "to draw women into their research projects" (p. 65). Efforts from faculty members are especially important because "female students may not be as assertive as males in seeking such experiences. Faculty should be sensitive to bright and articulate young women who would contribute to and profit from such activities" (p. 65).

2.3.3 Postcollege intervention

Companies and institutions can help women who are establishing a career. According to Klawe and Leveson [11], because women's most important years in establishing a research career often coincide with their childbearing years, providing good child-care facilities and arrangements can help with recruiting and retention of women faculty and industrial researchers. In addition to child-care facilities, good maternal leave policies that allow women to leave work to care for their young can also help retain women.

2.4 Spatial Ability between Women and Men

Peters et al. [23] conducted two studies with 51 male and 52 female first year engineering students. They used the Mental Rotations Test (MRT) to assess students' spatial ability. In the first study, they tested whether there was a difference in spatial ability among women and men and whether this difference affects students' course performance. Peters et al. administered an MRT test at the beginning of the semester and the same MRT test at the end of the semester. They found significant sex differences in both MRT tests. Because there were no significant sex differences on the course performance, the differences measured by the MRT do not appear to affect course performance. In the second study, Peters et al. improved the first study by eliminating the effects of repeated testing and class experience from the study. The students were split up into two groups. To eliminate the effects of repeated testing, the first group took MRT(A) at the beginning of the semester and MRT(B) at the end of the semester. MRT(A) and MRT(B) have different questions but have the same difficulty. To eliminate the effects of class experience, the second group took MRT(B) at the end of the semester. Peters et al. found that students in the first group performed better on MRT(B) than MRT(A), but explained that the improvement in performance can be the result of self-selection. In comparing the first group's MRT(B) results with the second group's MRT(B) results, Peters et al. inferred that the first group did better because students in the first group have had previous experience with taking an MRT test. In comparing the first group's MRT(A) results with the second group's MRT(B) results, Peter et al. found the two groups performed equally well.

2.5 Gender Differences in Student Performance and Attitudes

Felder et al. [15] conducted a longitudinal study on the performance and attitudes of women and men in chemical engineering courses. Students took five chemical engineering courses taught by the same instructor in five consecutive semesters. These five chemical engineering courses were designed to include cooperative learning because past studies indicate women perform better under cooperative learning compared with competitive grading.

Students completed the Learning and Study Strategies Inventory (LASSI) at the beginning of the first semester. LASSI is an instrument that assesses students' test-taking skills and strategies, motivation to learn, and anxiety levels. The results indicated that women have a higher anxiety level than men. However, women scored significantly higher than men on items relating to general attitudes toward learning, motivation to study, and use of study aids.

2.5.1 Difference in performance between genders

Men consistently received equal or higher grades in these five chemical engineering courses than women. The percentage of men earning A's was significantly greater than the percentage of women in two of the five courses. These results are unexpected because these courses had been designed to provide a friendly environment for women by incorporating cooperative learning. In addition, women came into engineering with better predictors of success: parents received higher education, higher SAT scores, and better study skills and strategies.

2.5.2 Difference in attitudes between genders

Men remained more confident about their academic preparation than woman throughout the five chemical engineering courses. "The women were more likely than the men to attribute poor performance to their own lack of ability and men were more likely to attribute it to a lack of hard work or being treated unfairly. Conversely, men were more likely than women to attribute success to their ability and women more likely than men to attribute it to outside help" [15, p. 157]. Men also rated their ability to solve basic engineering problems and more challenging problems requiring creativity significantly higher than women.

2.6 Dweck's Theory of Intelligence

Educational psychologist Carol Dweck [24] classifies people into two groups: incremental theorists and entity theorists. Incremental theorists believe that intelligence can improve with learning, but entity theorists believe intelligence cannot be changed. By conducting many research studies on how fifth-graders solve mathematical problems, Dweck found that incremental theorists and entity theorists differed when they face difficult problems. Entity theorists react by blaming themselves for not being smart enough, and incremental theorists react by saying the problem can be solved with more knowledge or effort. Incremental theorists believe they can solve any difficult problem with more learning, but entity theorists believe they can never solve some difficult problems because their intelligence level cannot be improved. Dweck also discovered that young women tend to be entity theorists. Consequently young women are more likely to give up on problems they think are too difficult.

2.7 Dweck's Theory in a College Environment

Heyman et al. [25] conducted a research project on gender and achievement-related beliefs among engineering and nonengineering students. The participants were 238 undergraduates enrolled at the University of California, San Diego. Among the 142 engineering students, 38 were women and 104 were men. Among the 96 non-engineering students, 57 were women and 39 were men.

Heyman et al. examined beliefs about engineering aptitude and general intelligence. Participants were asked about their engineering aptitude by rating their levels of agreement with the following two statements: (a) "You have a certain amount of aptitude for engineering, and you really can't do much to change it"; and (b) "You can learn new things, but you can't really change your basic aptitude for engineering." Based on the responses, each student was classified as either an incremental theorist or an entity theorist. Similar questions were used to assess beliefs about general intelligence; the phrase "aptitude for engineering" was replaced by "basic intelligence."

Heyman et al. also examined students' responses to difficulty. Participants were asked to think back to an incident in a college course in which they had had difficulties. They were asked to identify their responses to the difficulty from a set of forced-choice options: they dropped the class, worked less hard, worked about the same amount, or worked harder.

Heyman et al. found 72% of female engineering students hold entity beliefs about engineering aptitude. Only 46% of male engineering students hold entity beliefs about engineering aptitude. Thus, female engineering students are more likely to hold entity beliefs about engineering aptitude than male engineering students. No gender difference was found on beliefs about general intelligence.

Of the women who reported dropping a course when faced with difficulty, 100% held entity beliefs toward engineering aptitude. Of women who did not drop a course when faced with difficulty, only 61% held entity beliefs. No such relation between engineering aptitude and course dropping due to difficulty were seen among men.

Heyman et al.'s findings are consistent with Dweck's findings. Dweck found that young women are more likely to hold entity beliefs about their intelligence in general. Although Heyman et al. did not find such gender difference in basic intelligence; they did find a gender difference in engineering aptitude. Dweck found that entity theorists are more likely to fail when faced with difficulty. Heyman et al. found all women who failed when faced with difficulty held entity beliefs.

2.8 Dweck's Theory and Our Population

In our project, we chose to assess students' basic intelligence beliefs. If we find women do perform lower on exams and that they are more likely to be entity theorists, as suggested by Dweck, we then have evidence that women leaving engineering and computer science because they struggle through courses.

Like Heyman et al. [25], we administered a questionnaire to determine which students were entity theorists. Unlike Heyman et al., we used Dweck's "Theories of Intelligence Scale" questionnaire [24]. Some of the questions from Dweck's questionnaire are "You have a certain amount of intelligence, and you can't really do much to change it," and "Your intelligence is something about you that you can't change very much" [24]. Participants rated their agreement on a scale ranging from *strongly agree* (1) to *strongly disagree* (6). The surveys used in our project are provided in Appendix B, C, and D for ECE 110, ECE 290, and ECE 390, respectively.

CHAPTER 3
METHODS

3.1 Data Collection

To determine whether students' exam scores are correlated with gender, we collected examination scores and administered two surveys and a consent form in the Fall 2004 offerings of three core computer engineering courses at the University of Illinois at Urbana-Champaign: ECE 110, ECE 290, and ECE 390. These courses contain primarily freshmen, sophomores, and juniors and seniors, respectively. The courses include a mixture of electrical and computer engineering fundamentals, low-level programming, and data structures.

3.2 The Courses and Demographics

3.2.1 ECE 110

ECE 110, Introduction to Electrical and Computer Engineering, provides an integrated introduction to selected fundamental concepts and principles in electrical and computer engineering: circuits, electromagnetics, communications, electronics, controls, and computing. Lecture topics are coordinated with laboratory assignments involving the design and construction of an autonomous moving vehicle. Students earn four semester hours of credit for ECE 110. Each student enrolls in one lecture section and one three-hour laboratory section per week. In the fall of 2004, there were two lecture sections, each having three hourly lectures per week. Both lecture sections were taught by women, and the lab sections were taught by teaching assistants [26].

Most students in ECE 110 are freshmen majoring in general engineering, electrical engineering, or computer engineering. A total of 337 students were enrolled in the fall of 2004. Among those enrolled, 246 participated in our study. Among the participants, 28 were women and 218 were men.

3.2.2 ECE 290

ECE 290, Computer Engineering I, introduces students to digital logic and computer systems. The course covers the representation of information, combinational network analysis and design, sequential network analysis and design, and computer organization and control. Students earn three semester hours of credit for ECE 290. Each student enrolls in one lecture section which meets for two hours per week, and one hourly discussion section per week. In the fall of 2004, there were one lecture section and six discussion sections. In the first half of the semester, the lecture section was taught by a female instructor. In the second half of the semester, the lecture section was taught by a male instructor. The discussion sections were taught by teaching assistants.

Most students in ECE 290 are sophomores majoring in electrical engineering or computer engineering. A total of 194 students were enrolled in the fall of 2004. Among those enrolled, 154 participated in our study. Among the participants, 15 were women and 139 were men.

3.2.3 ECE 390

ECE 390, Computer Engineering II, covers the design and development of assembly language programs, including input-output, interrupts, multitasking, and basic data structures. Students earn three semester hours of credit for ECE 390. Lectures are 75 minutes long and are given twice per week. In the fall of 2004, ECE 390 was taught by a male instructor. A laboratory is available for students to complete assembly language machine problems 24 hours a day, seven days a week. The laboratory is staffed at least 5 hours per day, Monday through Friday. Students spend approximately 3 to 12 hours per week on machine problems, with an average of about 6 hours [27].

Most students in ECE 390 are juniors and seniors majoring in electrical engineering or computer engineering. A total of 88 students were enrolled in the fall of 2004. Among those enrolled, 72 participated in our study. Among the participants, 6 were women and 66 were men.

3.3 The Surveys

The "Background Information" surveys, provided in Appendices B, C, and D for ECE 110, ECE 290, and ECE 390, respectively, were administered at the beginning of the semester. This survey collected data on the students' gender, their ACT/SAT math scores, their experience with computers prior to college, and their study habits. Each survey included three questionnaires developed by Dweck [24]. The "Theories of Intelligence Scale" questionnaire classifies students as incremental theorists, entity theorists, or neither. After we have classified the students into three different categories, we can then determine whether women are more likely to be entity theorists than men, and whether entity theorists perform worse on exams than incremental theorists. The "Confidence in One's Intelligence" questionnaire measures students' confidence in their intelligence. After the students are categorized into being confident, not confident, or neither, we can determine whether students with confidence are more likely to be incremental theorists. The "Questionnaire Goal Choice Items" questionnaire gathers data on whether a student is performance oriented or learning oriented. We chose not to perform any statistical analysis on this data.

The "Experience from Class" surveys, provided in Appendices E, F, and G for ECE 110, ECE 290, and ECE 390, respectively were administered at the end of the semester. This survey collected data on total hours of study, the level of difficulty of exams, and study habits.

3.4 Scoring Dweck's Questionnaires

Dweck's "Theories of Intelligence Scale" questionnaire consists of four questions. Each question has six answer options: *strongly agree, agree, mostly agree, mostly disagree, disagree,* and *strongly disagree*. Each question is scored on a six-point scale [28]. The options have point values 1, 2, 3, 4, 5, and 6, respectively. An average score of 3.0 or less classifies the student as an entity theorist. An average score of 4.0 or more classifies the student as an incremental theorist. Students scoring between 3.0 and 4.0 are neither entity theorists nor incremental theorists.

Dweck's "Confidence in One's Intelligence" questionnaire presents students with three questions. Each question has two statements and a continuum. To answer these questions, students first pick the statement that is true for them and then indicate on the continuum how true the statement is. Students' marks on the continuum correspond to a six-point scale with choices of *very true for me*, *true for me*, and *sort of true for me*. The values on the continuum vary from 1 to 3 points or 4 to 6 points, depending on the statement selected. Indications along the continuum between discrete choices were interpolated to one decimal place. An average score of 3.0 or less suggests the student is not confident. An average score of 4.0 or more suggests the student is confident. Students scoring between 3.0 and 4.0 are neither not confident nor confident.

Dweck's "Questionnaire Goal Choice Items" questionnaire consists of four questions. The first three questions have six answer options: *strongly agree, agree, mostly agree, mostly disagree, disagree,* and *strongly disagree*. The first three questions are scored on a six-point scale. The options have point values 1, 2, 3, 4, 5, and 6, respectively. An average score of 3.0 or less suggests the student is performance oriented. An average score of 4.0 or more suggests the student is learning oriented. Students scoring between 3.0 and 4.0 are neither performance oriented nor learning oriented. The fourth question is provided with choices *good grade* and *being challenged*. This item checks results from the first three questions. If the result from the first three questions is inconsistent with the result from the fourth question, the student is considered neither performance oriented nor learning oriented.

CHAPTER 4
RESULTS AND ANALYSIS

In the fall of 2004, we administered the consent forms and surveys described in Chapter 3 in ECE 110, ECE 290, and ECE 390. In addition to the survey responses, we collected students' exam scores. Four students enrolled in STAT 427, Statistical Consulting, under the supervision of Professor Adam Martinsek at the University of Illinois at Urbana-Champaign, helped analyze the data. The following sections provide detailed information from their statistical analysis.

All exam scores in all courses were scaled linearly to the 0–100 range. Raw scores for both the ECE 110 final exam and the ECE 290 final exam actually ranged from 0 to 200. Raw scores for exam 1 and exam 2 of ECE 390 ranged from 0 to 150. Raw scores for the final exam in ECE 390 ranged from 0 to 250. Raw scores for all other exams ranged from 0 to 100.

4.1 Statistical Analysis of Women and Men's Exam Scores

In order to test whether women scored lower than men on exams, we first test the exam score data for normality. To characterize the sample distributions, histograms (Figure 1) were generated for all exams. In large samples, sample means have an approximate normal distribution by the central limit theorem. However in our sample, some of the distributions are noticeably skewed and therefore, are not normal. We applied the two-tailed *t* test to data with a normal distribution, and we applied the Mann-Whitney *U* test to data without a normal distribution. Tables 1–3 provide exam averages for men and women as well as *t* test and Mann-Whitney *U* test results for ECE 110, ECE 290, and ECE 390, respectively. Figures 2–4 consist of three bar charts, one for each course. Each bar chart shows the difference between the average exam scores of women and men.

In ECE 110, although the average score for women was slightly lower than that of men on each exam, this difference was not statistically significant at the 0.05 level. In ECE 290, the average scores for women were higher on the first two exams but lower for the final. Again, the differences of the averages on all exams were not statistically significant at the 0.05 level. In ECE 390, men averaged higher on exam 1 and exam 2. The differences in the averages were greater than the differences found in ECE 110 and ECE 290: 8.2 on exam 2, and 5.8 on the final exam. Although the differences are notably larger in ECE 390, they were again not statistically significant at the 0.05 level. For all three courses, we can conclude that women did not score significantly lower on exams than men.

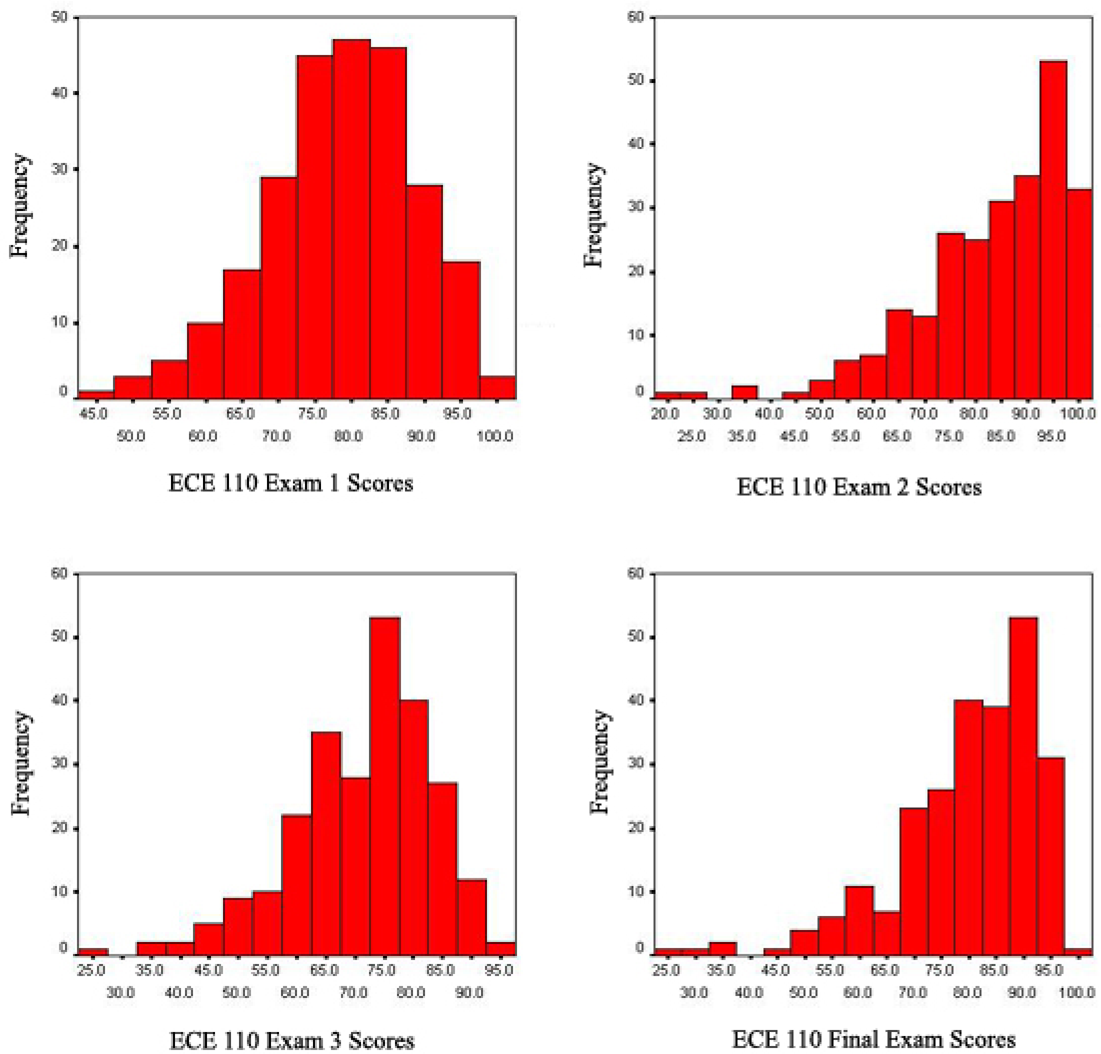

Figure 1. Histograms of the exam scores for all students

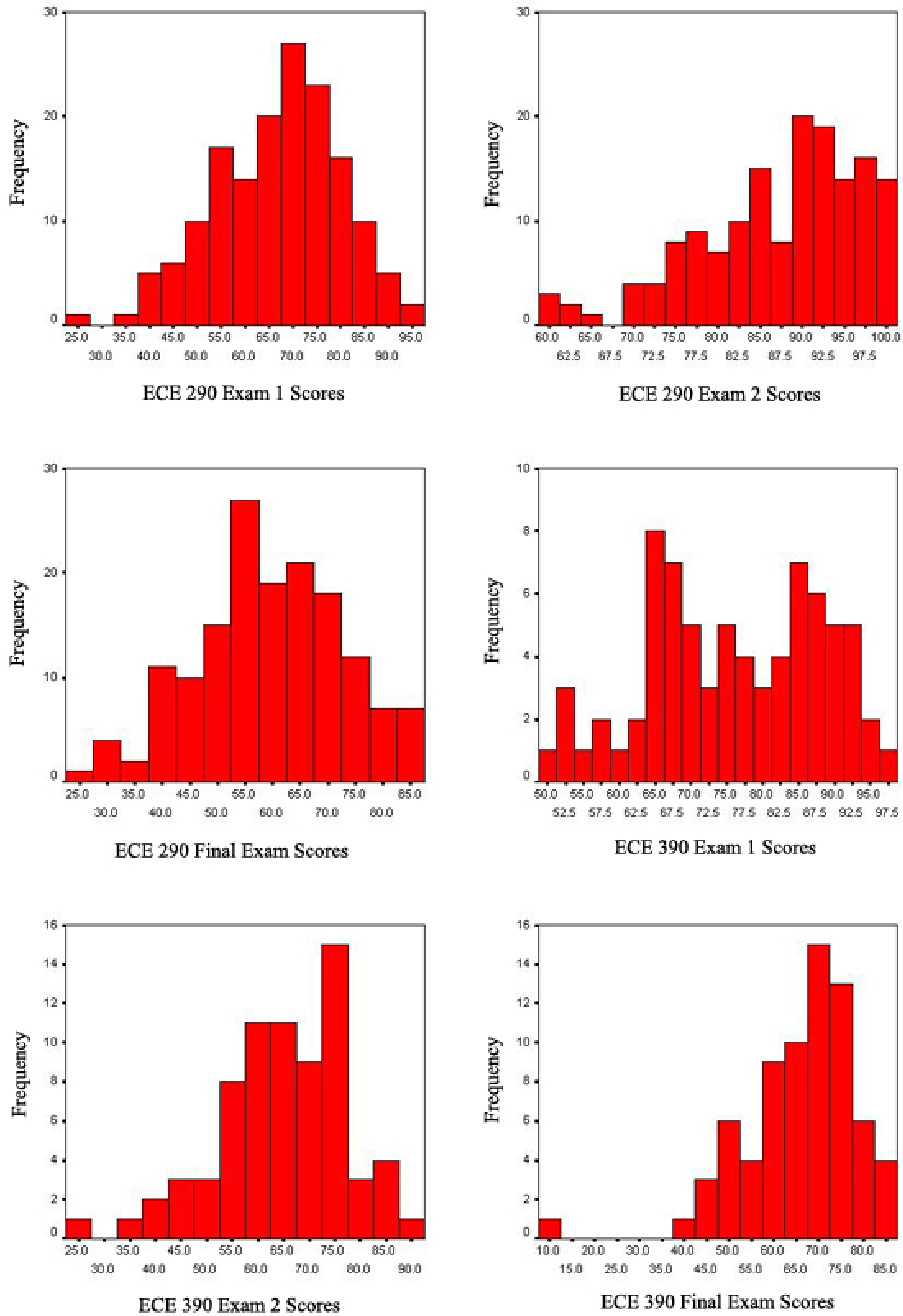

Figure 1. Continued

Table 1. Comparison of Exam Averages between Women and Men for ECE 110

		Female	Male	Significance
Exam 1	*n*	29	223	$p < 0.50$*
	Average	77.3	78.7	
	Std. Deviation	9.2	10.6	
Exam 2	*n*	29	222	$p < 0.79$*
	Average	82.5	83.4	
	Std. Deviation	15.0	14.3	
Exam 3	*n*	28	220	$p < 0.27$*
	Average	68.7	71.5	
	Std. Deviation	13.3	11.7	
Final Exam	*n*	28	218	$p < 0.90$*
	Average	80.1	80.2	
	Std. Deviation	13.7	13.0	

* Mann-Whitney *U* test.

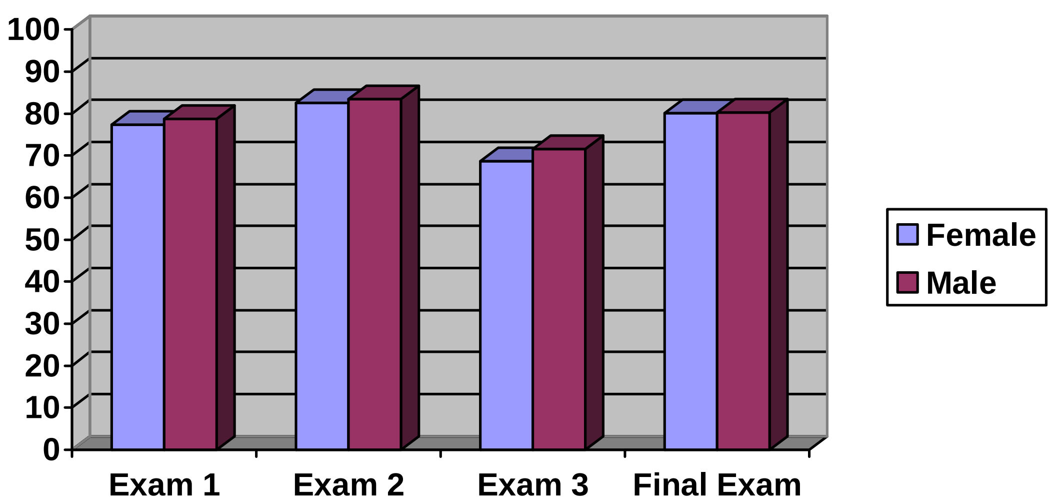

Figure 2. ECE 110 exam averages for women and men

Table 2. Comparison of Exam Averages between Women and Men in ECE 290

		Female	Male	Significance
Exam 1	*n*	15	142	$p < 0.80$**
	Average	67.8	67.0	
	Std. Deviation	11.7	13.3	
Exam 2	*n*	15	139	$p < 0.41$*
	Average	88.5	87.1	
	Std. Deviation	10.4	9.5	
Final Exam	*n*	15	139	$p < 0.77$**
	Average	58.2	59.2	
	Std. Deviation	12.3	13.4	

* Mann-Whitney *U* test. ** *t* test.

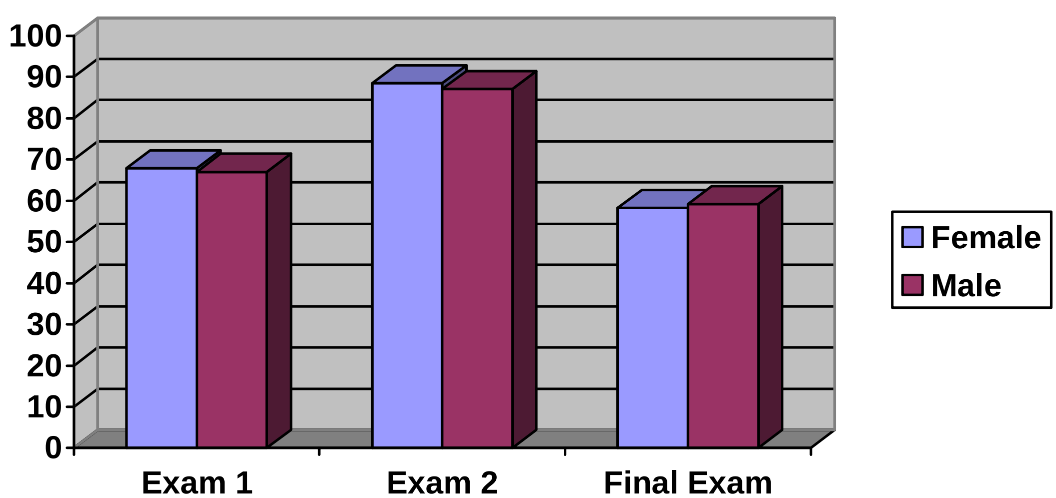

Figure 3. ECE 290 exam averages for women and men

Table 3. Comparison of Exam Averages between Women and Men in ECE 390

		Female	Male	Significance
Exam 1	*n*	7	68	$p < 0.97$**
	Average	76.1	75.9	
	Std. Deviation	11.0	12.4	
Exam 2	*n*	6	66	$p < 0.12$**
	Average	57.3	65.5	
	Std. Deviation	10.4	12.3	
Final Exam	*n*	6	66	$p < 0.25$*
	Average	60.4	66.2	
	Std. Deviation	12.5	12.3	

* Mann-Whitney *U* test. ** *t* test.

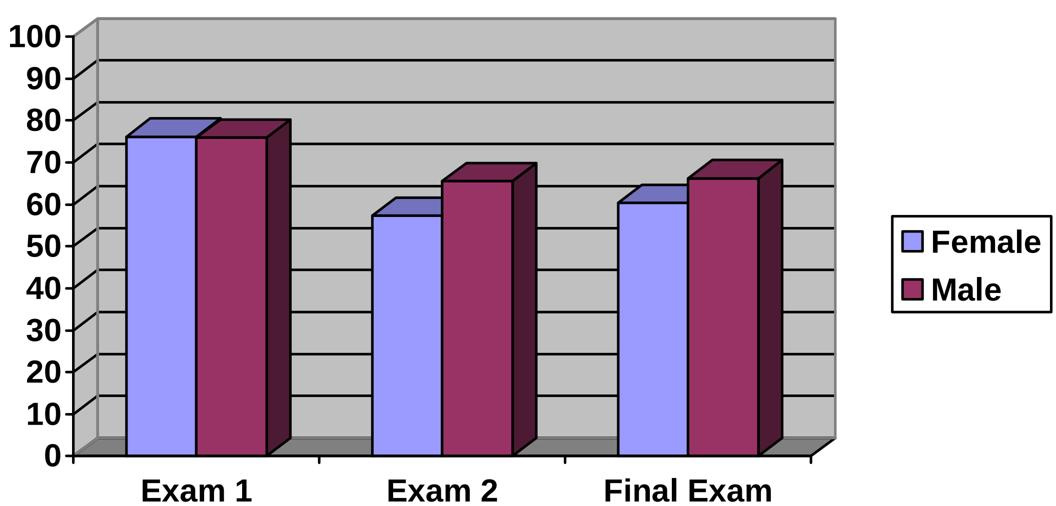

Figure 4. ECE 390 exam averages for women and men

Upon discovering no significant difference between exam averages of women and men on each exam, we wanted to test whether aggregate exam scores for each class would yield a significant difference. However, the histograms in Figure 1 show that some exams were normally distributed but others were not. Because the distributions of the exams differ from each other, we could not aggregate our data.

4.2 Outliers

We checked whether there were any outliers that could have affected the overall performance of women because the sample size of women in all classes was small. We generated histograms of women's exam scores for each exam to help identify any outliers. Figure 5 consists of 10 histograms, one for each exam. There were no obvious outliers.

4.3 Dweck's Theory on Our Population

We tested whether women are more likely than men to hold entity beliefs. Table 4 shows the percentages of participants' beliefs about intelligence by gender. Contrary to Dweck's findings, women are not more likely than men to hold entity beliefs in our population.

Table 4. Percentage of Participants' Intelligence Beliefs

		Intelligence Beliefs			
		Neither	Entity	Incremental	Total
ECE 110	Female	9 (31%)	7 (24%)	13 (44%)	29
	Male	36 (16%)	83 (37%)	104 (46%)	223
ECE 290	Female	7 (47%)	3 (20%)	5 (33%)	15
	Male	15 (11%)	57 (40%)	70 (49%)	142
ECE 390	Female	0 (0%)	4 (57%)	3 (43%)	7
	Male	6 (9%)	32 (47%)	30 (44%)	68

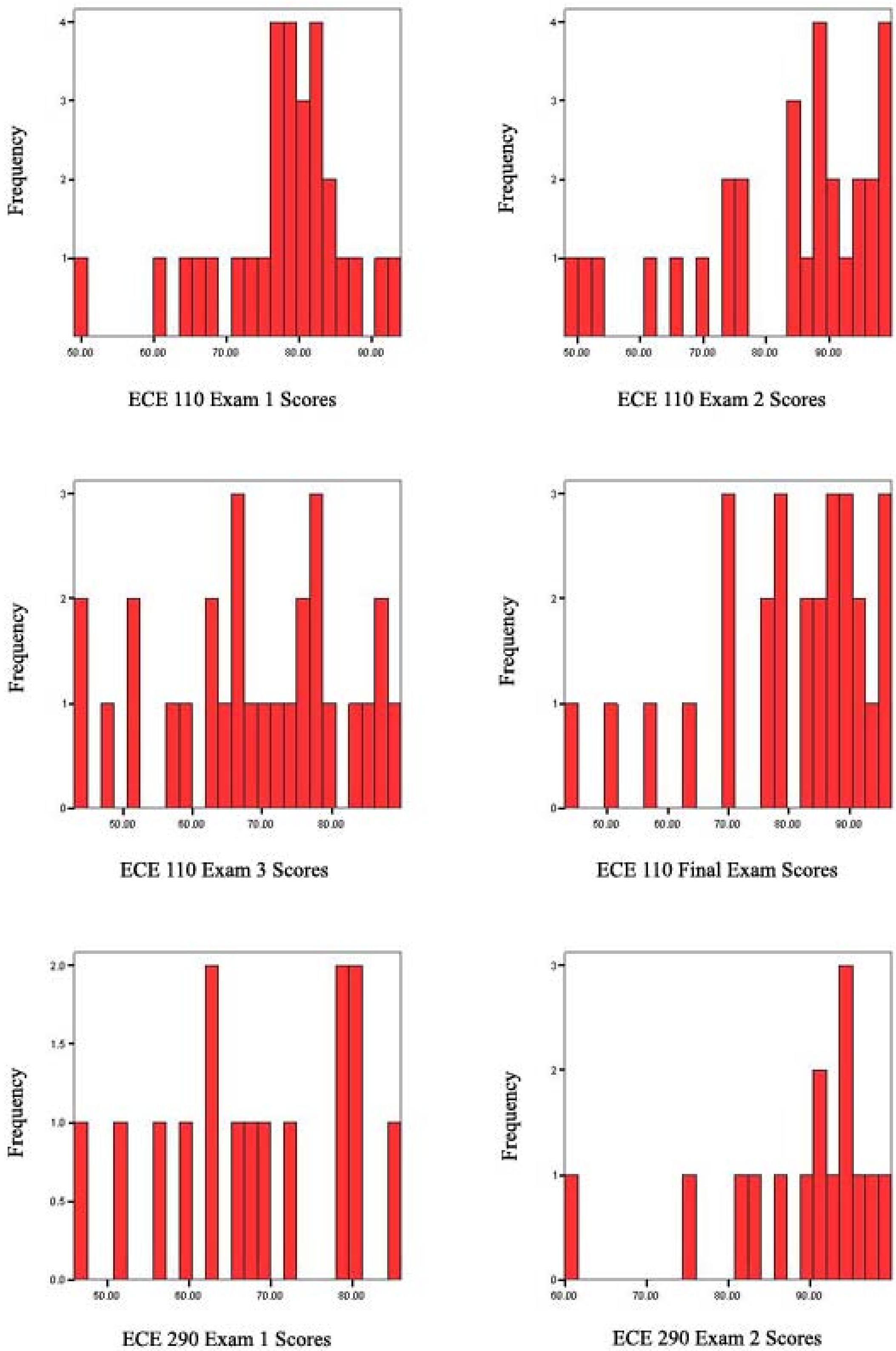

Figure 5. Histograms of the exam scores for women

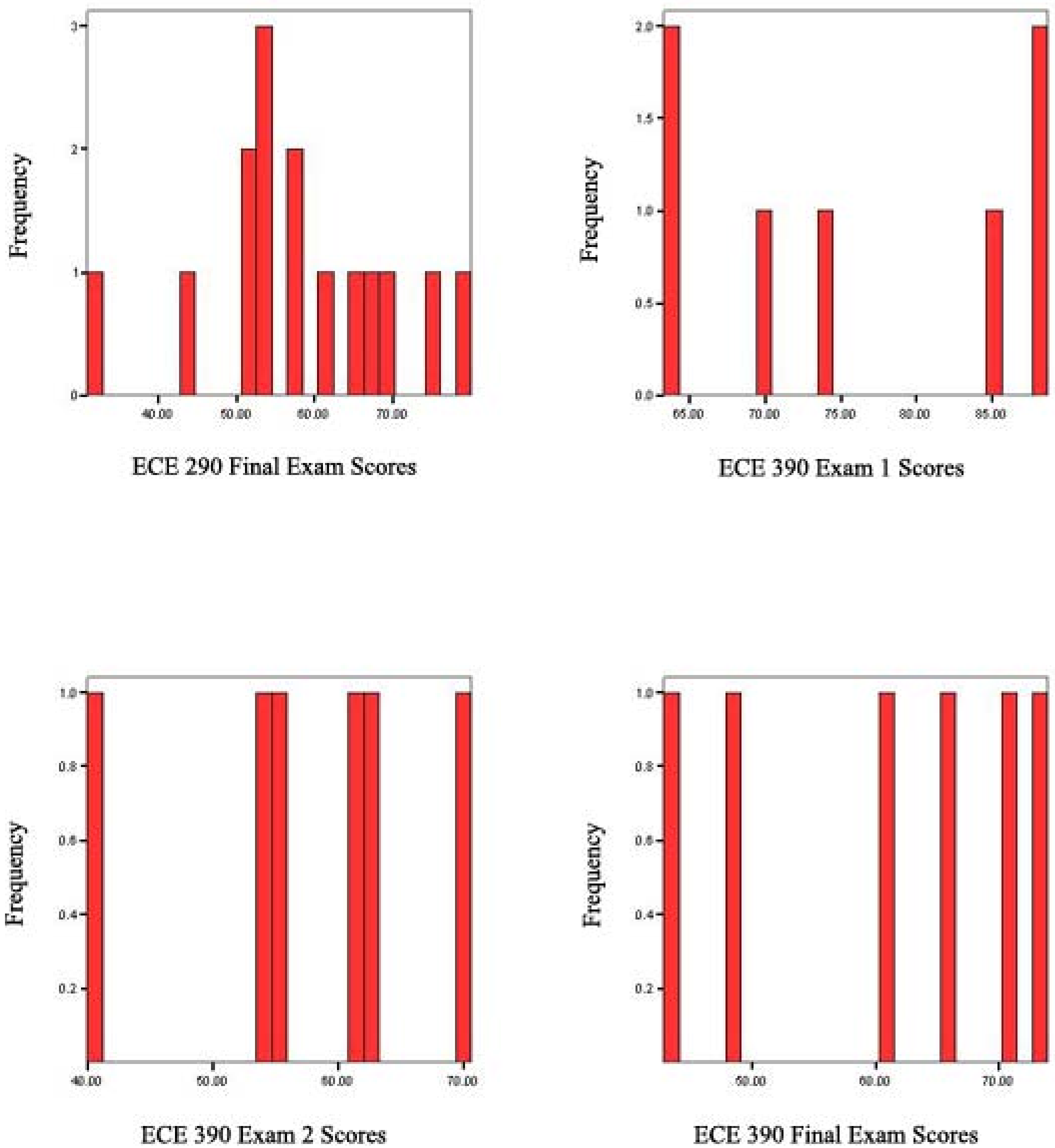

Figure 5. Continued

Dweck found that entity theorists perform worse on difficult problems than incremental theorists. To test whether entity theorists perform worse on exams in our population, we applied the two-tailed *t* test to data with a normal distribution, and we applied the Mann-Whitney *U* test to data without a normal distribution. Tables 5–7 provide exam averages for entity and incremental theorists as well as *t* test and Mann-Whitney *U* test results for ECE 110, ECE 290, and ECE 390, respectively. Figures 6–8 consist of three bar charts, one for each class. Each bar chart shows the difference between the average exam scores of entity and incremental theorists.

Although the differences between exam averages were statistically significant for exam 1 and the final exam in ECE 290, the entity theorists performed better. We can conclude that entity theorists do not score lower on exams.

Table 5. Comparison of Exam Averages between Entity and Incremental Theorists for ECE 110

		Entity Theorists	Incremental Theorists	Significance
Exam 1	*n*	90	117	$p < 0.28$*
	Average	79.4	77.1	
	Std. Deviation	9.5	11.3	
Exam 2	*n*	90	117	$p < 0.32$*
	Average	84.8	82.7	
	Std. Deviation	13.2	14.3	
Exam 3	*n*	88	116	$p < 0.11$*
	Average	71.9	69.9	
	Std. Deviation	12.4	11.8	
Final Exam	*n*	86	116	$p < 0.39$*
	Average	80.9	79.5	
	Std. Deviation	12.0	12.6	

* Mann-Whitney *U* test.

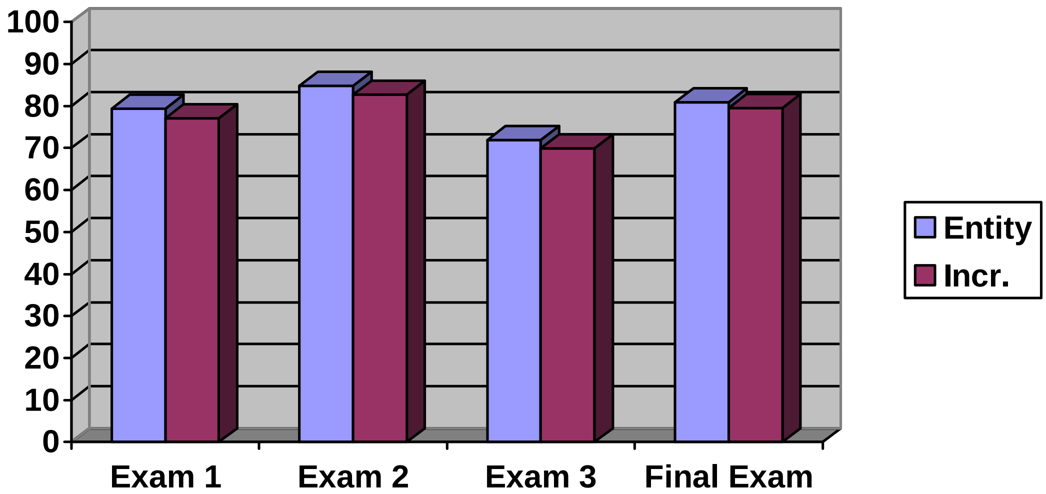

Figure 6. ECE 110 exam averages for entity and incremental theorists

Table 6. Comparison of Exam Averages between Entity and Incremental Theorists for ECE 290

		Entity Theorists	Incremental Theorists	Significance
Exam 1	*n*	60	75	$\mathbf{p < 0.05}$**
	Average	71.1	64.9	
	Std. Deviation	11.0	13.2	
Exam 2	*n*	59	73	$p < 0.057$*
	Average	88.9	86.2	
	Std. Deviation	9.0	9.1	
Final Exam	*n*	59	73	$\mathbf{p < 0.05}$**
	Average	62.7	57.1	
	Std. Deviation	13.9	11.9	

* Mann-Whitney *U* test. ** *t* test. Bold font indicates significance < 0.05.

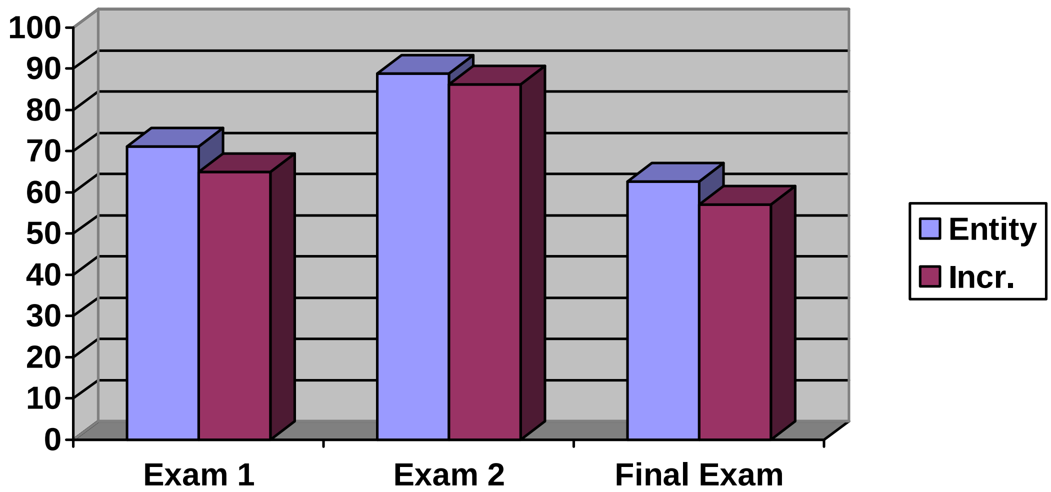

Figure 7. ECE 290 exam averages for entity and incremental theorists

Table 7. Comparison of Exam Averages between Entity and Incremental Theorists for ECE 390

		Entity Theorists	Incremental Theorists	Significance
Exam 1	*n*	36	33	$p < 0.48$*
	Average	76.7	74.3	
	Std. Deviation	9.6	13.8	
Exam 2	*n*	35	32	$p < 0.24$**
	Average	65.8	62.1	
	Std. Deviation	9.5	14.9	
Final Exam	*n*	35	32	$p < 0.44$*
	Average	67.0	63.3	
	Std. Deviation	9.4	15.0	

* Mann-Whitney *U* test. ** *t* test.

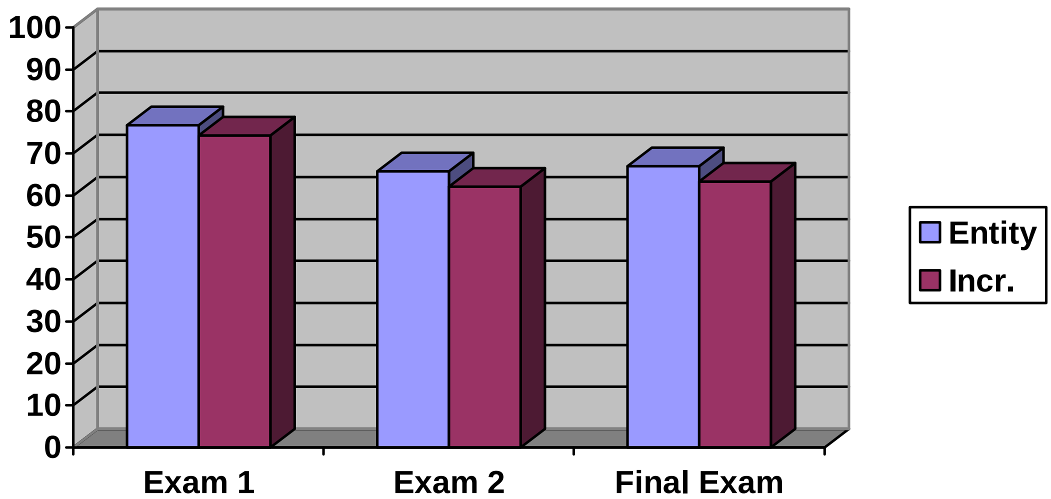

Figure 8. ECE 390 exam averages for entity and incremental theorists

4.4 Odds Ratio

According to Dweck [24], it is easier for incremental theorists to maintain confidence in the face of difficulties. To determine whether students with confidence in their intelligence hold incremental beliefs, odds ratios were used as a descriptive measure. In general, to calculate the odds ratio, we divide the probability that the event will happen by the probably that the event will not happen. If the odds ratio is greater than one, the event is more likely to happen than not.

For both women and men, the odds ratios suggest that students who are confident tend to have incremental beliefs. Due to the small sample size, the odds ratios are suggestive and not conclusive. No formal hypothesis test was conducted in part because of the small sample size. Tables 8–10 contain odds ratios for intelligence beliefs versus confidence in ECE 110, ECE 290, and ECE 390, respectively.

4.5 The Effect of ACT Math

Students were asked to give their ACT Math or SAT Math scores on the “Background Information” survey. Participants’ SAT Math scores were converted to ACT Math scores with a standard table used by the Office of Admissions and Records at the University of Illinois at Urbana-Champaign. The correlation between ACT Math scores and exam scores was evaluated with three different models.

Table 8. Odds Ratio of Students' Intelligence Beliefs versus Confidence in ECE 110

	Female Intelligence Beliefs		Male Intelligence Beliefs	
	Incremental	Entity	Incremental	Entity
Confident	12	7	98	73
Not Confident	0	0	1	4

Female:

Adjusted Odds Ratio: 1.67 = (12.5 * 0.5)/(7.5 * 0.5)

Male:

Odds Ratio: 5.37 = (98 * 4)/(73 * 1)
Adjusted Odds Ratio: 4.02 = (98.5 * 4.5)/(73.5 * 1.5)

Table 9. Odds Ratio of Students' Intelligence Beliefs versus Confidence in ECE 290

	Female Intelligence Beliefs		Male Intelligence Beliefs	
	Incremental	Entity	Incremental	Entity
Confident	4	2	60	44
Not Confident	0	0	2	9

Female:

Adjusted Odds Ratio: 1.80 = (4.5 * 0.5)/(2.5 * 0.5)

Male:

Odds Ratio: 6.14 = (60 * 9)/(44 * 2)
Adjusted Odds Ratio: 5.17 = (60.5 * 9.5)/(44.5 * 2.5)

Table 10. Odds Ratio of Students' Intelligence Beliefs versus Confidence in ECE 390

	Female Intelligence Beliefs		Male Intelligence Beliefs	
	Incremental	Entity	Incremental	Entity
Confident	2	1	29	22
Not Confident	1	2	1	4

Female:

Odds Ratio: 4.00 = (2 * 2)/(1 * 1)
Adjusted Odds Ratio: 2.78 = (2.5 * 2.5)/(1.5 * 1.5)

Male:

Odds Ratio: 5.27 = (29 * 4)/(22 * 1)
Adjusted Odds Ratio: 3.93 = (29.5 * 4.5)/(22.5 * 1.5)

4.5.1 A simple linear regression model

We used a simple linear regression model to evaluate the relationship between ACT Math scores and exam scores for women and men:

Male Students

$$ExamScore = \alpha_1 + \beta_1 ACT.Score$$

Female Students

$$ExamScore = \alpha_2 + \beta_2 ACT.Score$$

Table 11 provides detailed results. The *p*-value of less than 0.05 indicates that the correlation between ACT Math scores and exam scores is significant. Thus a student with a high ACT Math scores is more likely to score high on exams. The correlation coefficient r can be interpreted as follows: $r = 0$ indicates that there is no correlation between the two variables; $0 > r > 1$ indicates the two variables tend to increase and decrease together; $r = 1.0$ indicates a perfect correlation; $-1 > r > 0$ indicates one variable increases while the other decreases; $r = -1.0$ indicates a perfect inverse correlation. The best way to interpret r is to calculate R^2, which measures the percent of variation in the dependent variable that can be explained by the independent variables.

Table 11. Linear Regression Results for ACT Math and Exam Scores

		ECE 110		ECE 290		ECE 390	
		Female	Male	Female	Male	Female	Male
Exam 1	slope	2.21	1.31	0.36	1.71	1.46	1.69
	p	0.0017	0.000 001 9	0.65	0.000 015	0.22	0.014
	r	0.62	0.38	0.13	0.34	0.82	0.33
Exam 2	slope	1.80	1.34	0.63	1.14	1.00	1.01
	p	0.13	0.000 39	0.37	0.000 034	0.24	0.18
	r	0.32	0.30	0.26	0.34	0.88	0.18
Exam 3	slope	1.49	0.91	-	-	-	-
	p	0.077	0.0036	-	-	-	-
	r	0.38	0.24	-	-	-	-
Final	slope	2.10	0.79	0.92	1.56	2.53	1.66
	p	0.044	0.046	0.27	0.000 097	0.067	0.033
	r	0.42	0.18	0.32	0.30	0.93	0.27

The correlation coefficients for men are mostly around 0.30, with the exception of the final exam for ECE 110 and exam 2 for ECE 390. A correlation coefficient of 0.30 indicates a moderately weak correlation between ACT Math scores and exam scores. The results for men are statistically significant at the 0.05 level except for exam 2 in ECE 390.

The correlation coefficients for women in ECE 110 are moderately weak except for exam 1, where there is a medium correlation. However, the *p* values for exam 2 and exam 3 are greater than 0.05. The correlation coefficients for women in ECE 290 indicate weak to moderately weak correlations between ACT Math scores and exam scores. As with ECE 110 exams 2 and 3, the *p* values for all exams in ECE 290 are greater than 0.05. The correlation coefficients for women in ECE 390 indicate a strong correlation between ACT Math scores and exam scores. Due to small sample size and large *p* values, we cannot conclude that there exists a strong correlation between ACT Math scores and exam scores for women in ECE 390. The large *p* values for women reflect the small sample size, however.

4.5.2 Regression Model (1) and Model (2)

Two statistical models were used to determine whether women performed worse than men after controlling for ACT Math scores:

Model (1)

$$ExamScore = \hat{\beta}_0 + \hat{\beta}_1 Gender + \hat{\beta}_2 ACT.Score + \hat{\beta}_3 Gender \times ACT.Score$$

Model (2)

$$ExamScore = \hat{\alpha}_0 + \hat{\alpha}_1 ACT.Score + \hat{\alpha}_2 Gender \times ACT.Score$$

Gender = 0 if Male, Gender = 1 if Female

In Model (1), we are interested in the significance of $\hat{\beta}_1$ and $\hat{\beta}_3$. The term $\hat{\beta}_1$ is the difference in intercepts and $\hat{\beta}_3$ is the difference in slopes between genders. In Model (2), we are interested in the significance of $\hat{\alpha}_2$. The term $\hat{\alpha}_2$ is the difference in slopes between the genders. The results of Model (1) for ECE 110, ECE 290, and ECE 390 are displayed in Tables 12–14. The results of Model (2) for ECE 110, ECE 290, and ECE 390 are displayed in Tables 15–17.

The *t* value is the parameter estimate divided by its standard error. The *t* value expresses the parameter estimate in standard units. We can use the *t* value to interpret our results only when a particular variable is significant. In our results, variables Gender and Gender*ACT are not significant in Model (1) for any course or exam; therefore, the signs of the *t* values for those variables do not show whether the true parameter estimates are positive or negative. However, *p* values and positive parameter estimates for ACT Math scores indicate a significant correlation between ACT Math scores and exam scores: better ACT Math scores indicate better exam scores.

As in Model (1), Gender is not significant in Model (2). Therefore, the *t* value cannot be used to interpret the sign of the parameter estimates. However, *p* values for ACT Math scores and positive parameter estimates indicate a significant correlation between ACT Math scores and exam scores.

Table 12. Model (1) Results for ACT Math Scores and Gender for ECE 110

		Exam 1	Exam 2	Exam 3	Final
Gender	Parameter estimates ($\hat{\beta}_1$)	–29.84	–16.66	–20.99	–46.08
	t	–1.16	–0.46	–0.71	–1.39
	p	0.25	0.65	0.48	0.17
ACT	Parameter estimates ($\hat{\beta}_2$)	1.31	1.34	0.91	0.70
	t	4.98	3.57	2.96	2.01
	p	<0.0001	0.004	0.0034	0.046
Gender*ACT	Parameter estimates ($\hat{\beta}_3$)	0.90	0.46	0.59	1.40
	t	1.15	0.41	0.64	1.37
	p	0.25	0.68	0.52	0.17
R^2		0.13	0.066	0.053	0.038

Table 13. Model (1) Results for ACT Math Scores and Gender for ECE 290

		Exam 1	Exam 2	Exam 3
Gender	Parameter estimates ($\hat{\beta}_1$)	46.20	19.39	21.76
	t	1.67	0.98	0.77
	p	0.097	0.33	0.44
ACT	Parameter estimates ($\hat{\beta}_2$)	1.71	1.14	1.56
	t	4.49	4.20	4.03
	p	<0.0001	<0.0001	<0.0001
Gender*ACT	Parameter estimates ($\hat{\beta}_3$)	–1.35	–0.52	–0.64
	t	–1.55	–0.83	–0.72
	p	0.12	0.41	0.47
R^2		0.13	0.12	0.11

Table 14. Model (1) Results for ACT Math Scores and Gender for ECE 390

		Exam 1	Exam 2	Exam 3
Gender	Parameter estimates ($\hat{\beta}_1$)	6.65	–3.59	–31.58
	t	0.15	–0.070	–0.63
	p	0.88	0.94	0.53
ACT	Parameter estimates ($\hat{\beta}_2$)	1.69	1.01	1.66
	t	2.57	1.37	2.21
	p	0.013	0.18	0.031
Gender*ACT	Parameter estimates ($\hat{\beta}_3$)	–0.23	–0.0053	0.87
	t	–0.17	0	0.58
	p	0.87	0.99	0.56
R^2		0.12	0.052	0.14

Table 15. Model (2) Results for ACT Math Scores and Gender for ECE 110

		Exam 1	Exam 2	Exam 3	Final
ACT	Parameter estimates ($\hat{\alpha}_1$)	1.41	1.40	0.98	0.86
	t	5.7	3.97	3.41	2.64
	p	<0.0001	<0.0001	0.0008	0.0088
Gender*ACT	Parameter estimates ($\hat{\alpha}_2$)	–0.012	–0.05	–0.058	–0.01
	t	–0.17	–0.56	–0.75	–0.13
	p	0.86	0.58	0.45	0.90
R^2		0.12	0.065	0.051	0.030

Table 16 Model (2) Results for ACT Math Scores and Gender for ECE 290

		Exam 1	Exam 2	Exam 3
ACT	Parameter estimates ($\hat{\alpha}_1$)	1.42	1.02	1.42
	t	4.17	4.22	4.14
	p	<0.0001	<0.0001	<0.0001
Gender*ACT	Parameter estimates ($\hat{\alpha}_2$)	0.090	0.088	0.04
	t	0.79	1.09	0.35
	p	0.43	0.28	0.72
R^2		0.11	0.11	0.11

Table 17. Model (2) Results for ACT Math Scores and Gender for ECE 390

		Exam 1	Exam 2	Exam 3
ACT	Parameter estimates ($\hat{\alpha}_1$)	1.64	1.03	1.89
	t	2.88	1.64	2.95
	p	0.0055	0.11	0.0046
Gender*ACT	Parameter estimates ($\hat{\alpha}_2$)	–0.032	–0.11	–0.073
	t	–0.21	–0.63	–0.40
	p	0.84	0.53	0.69
R^2		0.12	0.052	0.13

4.6 Relationship between Gender and Exam Scores

We examined the relationship between gender and exam scores when controlling for total hours spent on a course. The number of hours spent on a course includes time spent on homework assignments, lab assignments or lab sessions, lectures, and studying. We used a linear model to test the relationship between gender and exam scores:

$$ExamScore = \alpha_1 + \beta_1 Gender + \hat{\beta}_2 Total.Hours$$

Fewer students took the "Experience from Class" surveys than took the "Background Information" surveys because the "Experience from Class" surveys were administered at the end of the semester, when fewer students attended classes. Since the data for total hours spent on a course was collected on the "Experience from Class" surveys, the number of students who responded differs from the demographics reported in Section 3.2. In ECE 110, ECE 290, and ECE 390, 105, 72, and 34 students responded to the "Experience from Class" surveys, respectively.

The results are displayed in Table 18. The "Overall *F*" value is the value of the *F* statistic for testing the hypothesis that neither *Gender* nor *Total.Hours* is significant. The null hypothesis is that both parameters are equal to zero. The *F* value for gender tests for significance of *Gender* when *Total.Hours* is included in the model. The null hypothesis is that the parameter for gender is zero with no assumptions made about *Total.Hours*. Because all *p* values are greater than 0.05, neither *Gender* nor *Total.Hours* has an effect; in particular, *Gender* has no effect whether or not *Total.Hours* is included in the model.

We examined the relationship between gender and exam scores when controlling for students who seek help. The term "help-seeking students" will be used from now on to refer to students who seek help from professors and teaching assistants when needed. The term *Help* will be used to refer to the variable that represents help-seeking students in our model. We used a linear model to test the relationship between gender, help-seeking, and exam scores:

$$ExamScore = \alpha_1 + \beta_1 Gender + \hat{\beta}_2 Help$$

Table 18. Linear Model Results when controlling for Total Hours

		Overall *F*	*p*	Gender *F*	*p*	R^2
ECE 110	Exam 1	2.17	0.097	0.36	0.55	0.061
	Exam 2	0.93	0.42	1.59	0.21	0.027
	Exam 3	1.16	0.33	0.07	0.78	0.033
	Final	0.63	0.60	1.06	0.31	0.018
ECE 290	Exam 1	0.67	0.57	0.23	0.63	0.029
	Exam 2	1.22	0.31	0.03	0.85	0.051
	Final	1.36	0.25	0.02	0.89	0.057
ECE 390	Exam 1	0.81	0.50	1.74	0.20	0.075
	Exam 2	2.50	0.079	2.96	0.10	0.200
	Final	2.38	0.090	1.40	0.25	0.190

The question we used to collected data on help-seeking students was on the "Experience from Class" surveys. The number of students who responded to the help-seeking question is the same as the number of students who responded to the total hours spent on a course question.

The results are displayed in Table 19. The "Overall *F*" value is the value of the *F* statistic for testing the hypothesis that neither *Gender* nor *Help* is significant. The null hypothesis is that both parameters are equal to zero. The *F* value for gender tests for significance of *Gender* when *Help* is included in the model. The null hypothesis is that the parameter for gender is zero with no assumptions made about *Help*. Because all *p* values are greater than 0.05, neither *Gender* nor *Help* has an effect; in particular, *Gender* has no effect whether or not *Help* is included in the model.

Table 19. Linear Model Results when controlling for Help-Seeking Students

		Overall *F*	*p*	Gender *F*	*p*	R^2
ECE 110	Exam 1	0.97	0.45	0.69	0.41	0.031
	Exam 2	0.09	0.96	0	0.98	0.0011
	Exam 3	0.34	0.79	0.06	0.81	0.0042
	Final	0.23	0.87	0.05	0.83	0.0028
ECE 290	Exam 1	1.05	0.40	0.30	0.58	0.054
	Exam 2	0.56	0.64	0.02	0.90	0.011
	Final	0.16	0.92	0.14	0.71	0.0032
ECE 390	Exam 1	1.06	0.37	1.57	0.21	0.043
	Exam 2	1.05	0.38	0.04	0.84	0.044
	Final	0.70	0.56	1.16	0.29	0.030

CHAPTER 5
CONCLUSIONS AND FUTURE WORK

In this study, we compared women's and men's exam scores in three core courses in computer engineering. We found that, compared with men, women do not score lower on exams. Thus, we cannot conclude that poor performance is a cause for low retention rate of women in computer engineering. We also tested Dweck's findings on our population. Contrary to Dweck's findings, we found that women are not more likely than men to be entity theorists. We also did not find that entity theorists perform worse on exams than incremental theorists.

Although this research yielded unexpected results, it is important to note the number of women was small. For statistical analyses, the larger the sample size, the better the quality of the result. We considered different ways of increasing the number of women in our study by aggregating exam scores and by conducting the same surveys in multiple semesters, but none were feasible. If we had had more women, then we may have found statistically significant differences in exam scores between women and men.

Few instructors in engineering and computer science are women. In ECE 110 and ECE 290, three out of the four instructors were women. Consequently, the women students in these courses may have performed better on exams than if the instructors had been men, for two reasons. First, the teaching methods used by the women instructors might have been more effective with women students than the methods typically used by male instructors. Second, the women students may have seen the women instructors as role models: the motivation and self-confidence of the women students may have improved. Further, the women students could have obtained more help and support from the women instructors than they would have from male instructors.

In Section 2.6, we discussed the study of Heyman et al. [25], who found that women are more likely to hold entity beliefs about their engineering aptitude but not about their basic intelligence. In our study, we should have used the engineering aptitude questions of Heyman et al. as well as the basic intelligence aptitude questions of Dweck to determine whether our population would yield the same result as the population of Heyman et al.

Dweck [24] suggested that entity theorists would perform better than incremental theorists when they are not faced with difficulty because entity theorists want to look smart amongst their peers. The "Questionnaire Goal Choice Items" questionnaire on the "Background Information" survey was intended for us to check Dweck's finding. Unfortunately, we did not have time to test whether entity theorists in our population are more likely to be performance oriented and incremental theorists in our population are more likely to be learning oriented.

Below is a list of questions for future studies which were generated by our study.

- How do women measure success? When and how do they think they are not doing well in school?
- Do women think they put more effort into courses than men do, and does this additional effort adversely affect their confidence in their academic abilities? In general, women think they are less intelligent than men because they require more explanations about engineering concepts and more help on homework assignments than men do, even when they have higher grades. According to Felder et al. [15], men do not correlate effort with intelligence. In particular, when men do not perform well on exams, they experience a smaller decrease in self-confidence than do women. When men earn poor exam grades, they tend to blame the instructors and the exam questions rather than themselves.
- Do women lack skills men have which are required for the success in engineering and computer science? As discussed in Section 2.4, on the first administration of the "Mental Rotations Test," women perform significantly worse than men. Although spatial ability is a skill required by mechanical and civil engineering, not all engineering disciplines, it is an example of how women have less of some of the abilities required by engineering than men. Although results indicate that women's lack of spatial abilities do not affect their course grades, it is possible that lack of other abilities can be a cause of poor performance in engineering and computer science courses for women.

APPENDIX A

CONSENT FORMS

Consent Form

Purpose and Procedures

The purpose of this research is to explore possible relationships between students' prior experiences, study habits, beliefs about academics, and exam performance. You will fill out two surveys during the semester pertaining to your study habits and computer background experiences. The two surveys should take approximately ten minutes each.

Voluntariness

Participation in this research is voluntary. You may refuse to participate or may discontinue participation at any time, by completing and dating a new form. Participation will not affect your grade in a course or status at this university.

Benefits and Risks

These surveys may help you clarify your beliefs regarding learning and intelligence. Because you may become more aware of your study habits, you might perform better in future courses. Participants may feel slightly embarrassed or concerned about their beliefs or academic performance.

Confidentiality

The data to be used in this research is limited to the survey answers and aggregated exam scores. In the event of publication of this research, no personally identifying information will be disclosed.

Whom to Contact with Questions

Questions about this research should be directed to I-Ju Liao (ijuliao@uiuc.edu). Questions about your rights as a research participant should be directed to the campus Institutional Review Board at (217) 333-2670.

Check One Box

☐ I certify that I have read this form, and I volunteer to participate in this research study.

☐ I do not wish to participate in this research study.

Please print name: ____

Signature: ______________________________ Date: ________________

APPENDIX B

BACKGROUND INFORMATION SURVEY FOR ECE 110

Fall 2004

Background Information for ECE 110

1. Name: ____

2. What is your gender? Male Female

3. What was your ACT math or SAT math score? _________

4. How old were you when you started using a computer? __________

5. Did anybody teach you how to program or assemble a computer before college? Y N

6. Was computer playing (programming, games, etc.) a hobby prior to college? Y N

7. Have you had a programming internship? Y N

8. Do you plan to become an engineer or enter a different profession?

____

9. Between the numbers 1 (low) and 10 (high), rate your level of effort for this course.

____

10. Do you think people with engineering degrees are respected more than others? Y N
Why or why not?

11. Upon completing a difficult task, does your confidence rise?

Always Usually Sometimes Rarely Never

12. When you need help, how often do you seek it from the instructor, a teaching assistant, or another student?

Always Usually Sometimes Rarely Never

13. Do you study with a group of students?

Always Usually Sometimes Rarely Never

Theories of Intelligence Scale

This questionnaire has been designed to investigate ideas about intelligence. There are no right or wrong answers.

1. You have a certain amount of intelligence, and you can't really do much to change it.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

2. Your intelligence is something about you that you can't change very much.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

3. To be honest, you can't really change how intelligent you are.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

4. You can learn new things, but you can't really change your basic intelligence.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

Confidence in One's Intelligence

1. Check the sentence that is most true for you.
_____ I usually think I'm intelligent.
_____ I wonder if I'm intelligent.

Now, show how true the statement you chose is for you. (indicate with an x)
|___________________________________|___________________________________|
very true for me   true for me   sort of true for me

2. Check the sentence that is most true for you.
_____ When I get new work in school, I'm usually sure I will be able to learn it.
_____ When I get new work in school, I often think I may not be able to learn it.

Now, show how true the statement you chose is for you.
|___________________________________|___________________________________|
very true for me   true for me   sort of true for me

3. Check the sentence that is most true for you.
_____ I'm not very confident about my intellectual ability.
_____ I feel pretty confident about my intellectual ability.

Now, show how true the statement you chose is for you.
|___________________________________|___________________________________|
very true for me   true for me   sort of true for me

Questionnaire Goal Choice Items

1. If I knew I wasn't going to do well at a task, I probably wouldn't do it even if I might learn a lot from it.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

2. Although I hate to admit it, I sometimes would rather do well in a class than learn a lot.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

3. It's much more important for me to learn things in my classes than it is to get the best grades.

Strongly Agree   Agree   Mostly Agree   Mostly Disagree   Disagree   Strongly Disagree

4. If I *had* to choose between getting a good grade and being challenged in class, I would choose… (Circle one)

"good grade"   "being challenged"

APPENDIX C

BACKGROUND INFORMATION SURVEY FOR ECE 290

Fall 2004

Background Information for ECE 290

1. Name: ____

2. What is your gender? Male Female

3. What was your ACT math or SAT math score? _________

4. How old were you when you started using a computer? __________

5. Did anybody teach you how to program or assemble a computer before college? Y N

6. Was computer playing (programming, games, etc.) a hobby prior to college? Y N

7. Have you had a programming internship? Y N

8. Do you plan to become an engineer or enter a different profession?

____

9. Between the numbers 1 (low) and 10 (high), rate your level of effort for this course.

____

10. Do you think people with engineering degrees are respected more than others? Y N
Why or why not?

11. Upon completing a difficult task, does your confidence rise?

Always Usually Sometimes Rarely Never

12. When you need help, how often do you seek it from the instructor, a teaching assistant, or another student?

Always Usually Sometimes Rarely Never

13. Do you study with a group of students?

Always Usually Sometimes Rarely Never

Theories of Intelligence Scale
This questionnaire has been designed to investigate ideas about intelligence. There are no right or wrong answers.

1. You have a certain amount of intelligence, and you can't really do much to change it.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

2. Your intelligence is something about you that you can't change very much.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

3. To be honest, you can't really change how intelligent you are.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

4. You can learn new things, but you can't really change your basic intelligence.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

Confidence in One's Intelligence
1. Check the sentence that is most true for you.
_____ I usually think I'm intelligent.
_____ I wonder if I'm intelligent.

Now, show how true the statement you chose is for you. (indicate with an x)
|___________________________________|___________________________________|
very true for me true for me sort of true for me

2. Check the sentence that is most true for you.
_____ When I get new work in school, I'm usually sure I will be able to learn it.
_____ When I get new work in school, I often think I may not be able to learn it.

Now, show how true the statement you chose is for you.
|___________________________________|___________________________________|
very true for me true for me sort of true for me

3. Check the sentence that is most true for you.
_____ I'm not very confident about my intellectual ability.
_____ I feel pretty confident about my intellectual ability.

Now, show how true the statement you chose is for you.
|___________________________________|___________________________________|
very true for me true for me sort of true for me

Questionnaire Goal Choice Items

1. If I knew I wasn't going to do well at a task, I probably wouldn't do it even if I might learn a lot from it.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

2. Although I hate to admit it, I sometimes would rather do well in a class than learn a lot.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

3. It's much more important for me to learn things in my classes than it is to get the best grades.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

4. If I *had* to choose between getting a good grade and being challenged in class, I would choose… (Circle one)

"good grade" "being challenged"

APPENDIX D
BACKGROUND INFORMATION SURVEY FOR ECE 390

Fall 2004

Background Information for ECE 390

1. Name: ____

2. What is your gender? Male Female

3. What was your ACT math or SAT math score? _________

4. How old were you when you started using a computer? __________

5. Did anybody teach you how to program or assemble a computer before college? Y N

6. Was computer playing (programming, games, etc.) a hobby prior to college? Y N

7. Have you had a programming internship? Y N

8. Do you plan to become an engineer or enter a different profession?

____

9. Between the numbers 1 (low) and 10 (high), rate your level of effort for this course.

____

10. Do you think people with engineering degrees are respected more than others? Y N
Why or why not?

11. Upon completing a difficult task, does your confidence rise?

Always Usually Sometimes Rarely Never

12. Courses completed before ECE 390 or equivalent courses elsewhere

CS 101 CS 125 CS 225 ECE 199SJP

13. Prior experience in assembly language

None (e.g., ECE 290 only) Some (e.g., ECE 199SJP) Extensive

14. When you need help, how often do you seek it from the instructor, a teaching assistant, or another student?

Always Usually Sometimes Rarely Never

15. Do you study with a group of students?

Always Usually Sometimes Rarely Never

Theories of Intelligence Scale
This questionnaire has been designed to investigate ideas about intelligence. There are no right or wrong answers.

1. You have a certain amount of intelligence, and you can't really do much to change it.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

2. Your intelligence is something about you that you can't change very much.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

3. To be honest, you can't really change how intelligent you are.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

4. You can learn new things, but you can't really change your basic intelligence.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

Confidence in One's Intelligence
1. Check the sentence that is most true for you.
_____ I usually think I'm intelligent.
_____ I wonder if I'm intelligent.

Now, show how true the statement you chose is for you. (indicate with an x)
|___________________________________|___________________________________|
very true for me true for me sort of true for me

2. Check the sentence that is most true for you.
_____ When I get new work in school, I'm usually sure I will be able to learn it.
_____ When I get new work in school, I often think I may not be able to learn it.

Now, show how true the statement you chose is for you.
|___________________________________|___________________________________|
very true for me true for me sort of true for me

3. Check the sentence that is most true for you.
_____ I'm not very confident about my intellectual ability.
_____ I feel pretty confident about my intellectual ability.

Now, show how true the statement you chose is for you.
|___________________________________|___________________________________|
very true for me true for me sort of true for me

Questionnaire Goal Choice Items

1. If I knew I wasn't going to do well at a task, I probably wouldn't do it even if I might learn a lot from it.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

2. Although I hate to admit it, I sometimes would rather do well in a class than learn a lot.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

3. It's much more important for me to learn things in my classes than it is to get the best grades.

Strongly Agree Agree Mostly Agree Mostly Disagree Disagree Strongly Disagree

4. If I *had* to choose between getting a good grade and being challenged in class, I would choose… (Circle one)

"good grade" "being challenged"

APPENDIX E

EXPERIENCE FROM CLASS SURVEY FOR ECE 110

Fall 2004

Experience from ECE 110

1. Name: ____

2. How many hours do you spend on ECE 110 per week? _____ hours
   (Please include lectures, readings, labs, and homework assignments)

3. Did you
   - like the material on exam 1? Yes No
   - like the material on exam 2? Yes No
   - like the material on exam 3? Yes No

4. How would you rate the material on exam 1?

   Very difficult Difficult Average Easy Very easy

5. How would you rate the material on exam 2?

   Very difficult Difficult Average Easy Very easy

6. How would you rate the material on exam 3?

   Very difficult Difficult Average Easy Very easy

7. When you need help, how often do you seek it from the instructor, a teaching assistant, or another student?

   Always Usually Sometimes Rarely Never

8. Do you study with a group of students?

   Always Usually Sometimes Rarely Never

APPENDIX F

EXPERIENCE FROM CLASS SURVEY FOR ECE 290

Fall 2004

Experience from ECE 290

1. Name: ____

2. How many hours do you spend on ECE 290 per week? _____ hours
   (Please include lectures, readings, lab assignments, and homework assignments)

3. Did you
   like the material on exam 1? Yes No
   like the material on exam 2? Yes No

4. How would you rate the material on exam 1?

   Very difficult Difficult Average Easy Very easy

5. How would you rate the material on exam 2?

   Very difficult Difficult Average Easy Very easy

6. When you need help, how often do you seek it from the instructor, a teaching assistant, or another student?

   Always Usually Sometimes Rarely Never

7. Do you study with a group of students?

   Always Usually Sometimes Rarely Never

APPENDIX G

EXPERIENCE FROM CLASS SURVEY FOR ECE 390

Fall 2004

Experience from ECE 390

1. Name: ____

2. How many hours do you spend on ECE 390 per week? _____ hours
   (Please include lectures, readings, machine problems, lab experiments and homework)

3. Did you
   like the material on exam 1? Yes No
   like the material on exam 2? Yes No

4. How would you rate the material on exam 1?

   Very difficult Difficult Average Easy Very easy

5. How would you rate the material on exam 2?

   Very difficult Difficult Average Easy Very easy

6. When you need help, how often do you seek it from the instructor, a teaching assistant, or another student?

   Always Usually Sometimes Rarely Never

7. Do you study with a group of students?

   Always Usually Sometimes Rarely Never

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