The Relationship between Self Efficacy, Critical Thinking, Grades, and the Quality of First Year Engineering Students

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Abstract

It is hypothesized that four qualities including strong content knowledge, good critical thinking skills, high self efficacy, and a high cognitive thinking level define a successful student. In an effort to increase these qualities in first year engineering students at the University of Nevada, Reno, new course content was developed for a pair of first-year classes, which also utilized teaching methods that were customized to how people learn most efficiently. Analysis of Variance (ANOVA) and Pearson's correlation were used to study the relationship between content knowledge, self efficacy, cognitive level, and critical thinking level.

It was found that critical thinking and self efficacy scores are positively correlated with each other, but neither is correlated with the student's course grade. In addition students who stated that they believed they would earn an 'A' in the first year course performed significantly better in critical thinking. Critical thinking and self efficacy scores did not have a correlation with overall course grades, which suggests that course grades may not be the best method for defining the quality of a student. This research supports the common belief held by many faculty: student grades are not the best indicator of student quality.

Introduction

Critical thinking is the process of gathering information and actively analyzing, synthesizing, applying, or evaluating it in order to make decisions, form beliefs, or choose a course of action [1]. Increasing engineering students' critical thinking skills is important because the higher their critical thinking level, the more successful they will be in solving problems. Students must think critically in order to gather data to solve problems, defend their solutions to problems, make open minded decisions, and communicate their ideas.

Critical thinking is typically measured in terms of skills associated with analysis, inference, evaluation, inductive reasoning, and deductive reasoning to give a total critical thinking skill score. Analysis skills are employed to dissect arguments that separate the assumptions a person is making from the conclusions they have drawn based on those assumptions. Inference skills are used to draw conclusions based on concrete evidence and rationale. Evaluation skills are those used to determine if an argument or idea is believable. Inductive reasoning skills are employed when we use what we know to infer a correct answer. Deductive reasoning leads us to believe something cannot be false if all of the foundations of our argument are true [2].

Self Efficacy refers to one's beliefs in their capabilities to organize and execute the courses of action required to produce given attainments [3].Self efficacy affects the choice of actions that people take, the manner of which they complete those actions, the effort, stress, perseverance, and resilience they exhibit when faced with challenges to completing their goals, and the level of

success they reach [3, 4]. Self esteem and self efficacy are closely related and important to education, but they are fundamentally different. While self esteem answers the question, "how good of a person am I?" self efficacy answers the question, "how well can I accomplish this task?" [5].

Self efficacy affects how students perform in solving engineering problems, as well as their retention in engineering curriculums. Professors can help students increase their self efficacy by providing goals, encouragement, mastery experiences, vicarious experiences, and stress coping strategies which will help students be more successful in engineering classes [4].

Since we know that self efficacy affects student success level it is important to not only provide ways to increase self efficacy, but also to monitor self efficacy. Bandura [3] has clear guidelines for designing self efficacy surveys. He stresses that when constructing self efficacy scales, one should make sure they are measuring self efficacy, or belief in one's capability, not self esteem, which is belief in one's self. The standard method for constructing a self efficacy survey is to ask individuals to rate their belief in their ability to perform a specific task. Subjects rate their efficacy on a likert scale that ranges from zero or no confidence to 100 or high confidence.

Cognition is the process of knowing, applying knowledge, and changing preferences. There are two popular methods for measuring cognitive levels including Perry's Model and King and Kitchener's Reflective Judgment (RJ) model. Both models are similar in classification although Perry's model contains two extra positions at the higher end of the scale [6, 7].

According to one major study that utilized the RJ model, engineering freshmen start and end college with a slightly higher cognitive level than liberal arts students, however, their cognitive growth over four years of college is less than liberal arts majors [7]. The small growth in cognitive levels during college could be a problem for engineering students in the future because of globalization. As the world becomes flatter due to advances in communication and ease of travel, American engineering graduates may find their jobs being outsourced to their foreign counterparts who can and will work for much less money [8, 9]. Low cognitive levels are also a problem for engineers because it affects their decision making skills. People need to think cognitively at higher levels in order to make educated decisions, which they are able to defend in order to survive in the current job market [10].

Grades are often seen as a measure for program and knowledge evaluation, but they often are not a true measure of ability. Programs that have students in them with higher grades on average are often seen as more successful programs, but these grades are often impure measures of ability [4]. When people evaluate grades, they do not know the inherent variation or history of the grade. Grades are subject to numerous variables, independent of student ability and effort, including tough and easy professors, inflation within the university or program culture, curves applied to the class, etc. Rojstaczar created a web site to highlight the rise of grades in colleges and universities. He claims that grades continue to rise despite the fact that students spend half the time studying now than students enrolled in college 40 years ago. The average grade point averages (GPAs) at public and private universities were 3.0 and 3.3 respectively in 2007 [11]. Figure 1 shows a gradual inflation of GPA for 70 private and public universities in the United States [12].

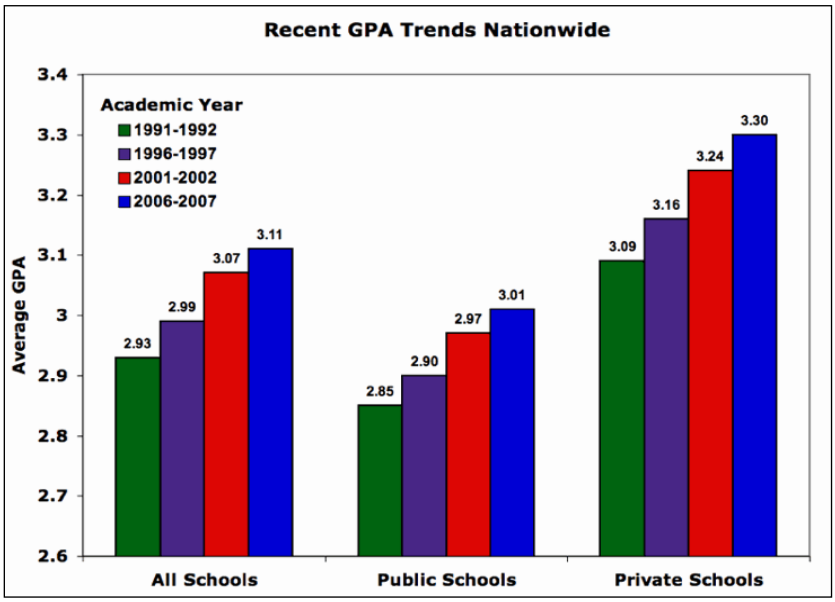


Figure 1 shows nationwide grade inflation trends. All universities had an average increase in GPA of 0.18 on a 4 point scale between 1991 and 2007.

The objective of this research was to determine if critical thinking, self efficacy, and grades are correlated in any way. This research was motivated by the common belief held by many faculty: student grades are not the best indicator of student quality.

Methods

Sampling

The Mechanical Engineering (ME) and Material Science Engineering (MSE) Departments at the University of Nevada, Reno have developed a required multi-disciplinary first-year engineering course with funding from the William and Flora Hewlett Foundation [13]. Traditionally this course has a combined enrollment of approximately 150 students.

The course is held in a computer laboratory with 24 students at a time, working in pairs. The class alternates between a workshop and a mini design project every other week. During the weeks in which a workshop format is used, the class consists of an interrupted lecture where students alternate between listening for brief periods and then actively participating (i.e., programming). LEGO® robots were used so that students would have a tangible application for their computer programs. Projects and assignments were designed to improve critical thinking skills and cognitive development.

Participants in this study were all mechanical engineering students enrolled in this interdisciplinary course in the spring of 2009, who volunteered to take a critical thinking test and several self efficacy surveys. Subjects were mainly freshmen between the ages of 18 and 20.

The authors evaluated the quiz scores and final grades of the students who participated in both the critical thinking test and the self efficacy surveys. Researchers did not expect the quiz

scores, critical thinking scores, and self efficacy scores to correlate significantly with final grades, since final grades are curved in this class. An application was submitted and approved with the Institutional Review Board (IRB) so that the critical thinking tests could be given and the results published.

Critical thinking tests

This research utilized the California Critical Thinking Skills Test (CCTST) to determine critical thinking levels because it has an appropriate level of difficulty for college students, it is easy to obtain and administer, and it is relatively inexpensive. The CCTST covers the five critical thinking skills identified by the Delphi experts including analysis, inference, evaluation, inductive reasoning, and deductive reasoning skills [2]. The CCTST is a multiple choice test offered online that takes approximately 45 minutes to complete.

Self Efficacy Tests

Self Efficacy was tested using a survey, created by the authors, based on Bandura's guide to constructing self efficacy scales [14]. The survey was given online, via SurveyMonkey.com, four times to the students during the spring of 2009. The first 4 groups of questions on the self efficacy survey involved students ranking, on a scale of 0-100, their degree of confidence, how much they value being able to perform, how successful they would be, and their anxiety level toward a list of tasks that make up the 10 learning objectives for course. Details concerning the learning objectives have been previously published [15]. Total self efficacy was determined to be the average value of the student's response.

Cognitive Development Essays

In this research, the cognitive level of each student will be tested via review of writing samples that were designed based on classic cognitive level interview questions. Students provided approximately 7 writing samples in during the semester. With these samples researchers will determine the student's level of cognitive development according to the RJ model, which will be used as the quantifiable measure of cognitive development. This portion of the research is currently in process and, thus, no results will be presented.

Content Knowledge Quizzes

In this research, quiz grades were the primary measurement of content knowledge. Students take two quizzes in the course that were designed to measure their content knowledge based on the course learning objectives.

Procedure

Students enrolled in the course (ME 151) in the spring of 2009 were given the self efficacy survey during class 4 times throughout the semester. The CCTST was offered once online at the end of the semester. Students were asked to take the CCTST, but it was not required in order to follow guidelines set by the Institutional Review Board. Students provided approximately 7

writing samples in ME 151 that were due after the completion of each mini design project. Self efficacy scores, critical thinking scores, cognitive development levels, quiz grades, and overall grades were compared using ANOVA and Pearson's correlation coefficient in SPSS (SPSS Inc, Chicago, Illinois) for those students who participated in self efficacy and critical thinking tests.

Results and Discussion

Since this project is a work-in-progress, not all of the data has been processed. Specifically, the cognitive development essays have not been coded yet. Nonetheless, results for the remaining three categories (critical thinking, self efficacy, and grades) are presented and have yielded intriguing results.

Table 1: Mean and standard deviation for the CCTST scores, self efficacy scores, and course grades.

2005	Average	Stn Dev
Final Grade	87.80	8.43
Quiz 2	47.50	17.43
Quiz 1	56.60	22.72
2006		
Final Grade	86.72	8.97
Quiz 2	74.22	19.69
Quiz 1	58.97	14.40
2007		
Final Grade	85.30	7.75
Quiz 2	71.08	15.35
Quiz 1	71.93	17.83
2008		
Final Grade	84.96	11.65
Quiz 2	68.26	19.94
Quiz 1	71.93	18.81
2009		
Final Grade	88.86	5.39
Quiz 2	77.92	19.14
Quiz 1	76.85	18.18
Crit. Think.	18.653	5.288
Self Eff. Ave.	76.79	19.63

Table 1 shows descriptive statistics for the CCTST results (2009), self-efficacy scores (2009), and quiz and course grades (2005 through 2009). The small difference in the averages of the course grades evaluated between 2005 and 2009 are not statistically significant and the standard deviations are very close indicating that the grades do not vary much. This is predictable since the course grades are curved at the end of the semester.

The CCTST was given once in 2009 to students enrolled in ME 151 at the end of the semester. The average score of on the CCTST was 18.653 and a standard deviation of 5.288. The national average on the CCTST is 16.801 with a standard deviation of 5.062. These scores were drawn from a population of a 2,677 four-year college students, of which 40% were first year students, 20% sophomore/junior level students, and 40% seniors level students [16]. Demographics and majors were not listed for these students so a direct comparison cannot be drawn, however the students enrolled in ME 151 did perform slightly better than those from the normal population.

In order to test for a statistically significant difference between the quiz grades over the five year period, the authors performed an ANOVA which compared quiz 1 and quiz 2 grades between 2005 and 2009. Since the ANOVA indicated significant results, Tukey's test was used for post hoc analysis to indicate which years had significantly different quiz grades. Tables 2 and 3 show the results of Tukey's post hoc test for quizzes 1 and 2. Quiz grades vary significantly if the significance level is less than or equal to 0.05.

According to the results shown in Table 2, quiz 1 averages are significant between 2005 and 2006 when compared with 2007, 2008, 2009. There is not a significant difference in scores

between 2005 and 2006 or 2008 and 2009. Many changes were made to the ME 151 course to increase content knowledge between 2006 and 2008, so it makes sense that students would have higher content knowledge. Changes included scaffolding the curriculum, online video tutorials, use of a pseudo-code online learning module, use of a concept inventory, and use of projects with real world context.

Table 2 shows the mean difference (I-J) between quiz 1 scores. Statistically significant differences (level is less than or equal to 0.05) are shown in bold *italic* font.

Quiz 1	Year (J)			
Year (I)	2006	2007	2008	2009
2005	***-2.37***	***-15.33***	***-15.32***	***-20.25***
2006		***-12.96***	***-12.95***	***-17.88***
2007			0.01	-4.92
2008				-4.92

Table 3 shows the results of Tukey's post hoc test on quiz 2 grades between 2005 and 2009. Significant changes to quiz averages exist between 2005 and every other year as well as a significant change between 2008 and 2009. 2005 was the first year that quiz 2 was administered and since the class scored an average of 47.5, instructors determined that the exam was too difficult. The exam was changed in 2006 to be simpler and so the average grades increased significantly. The significant change between 2008 and 2009 can be attributed to the fact that pseudo-code, which is heavily weighted in quiz 2, was emphasized throughout the semester rather than just at the end of the semester.

Table 3 shows the mean difference (I-J) between quiz 2 scores. Statistically significant differences (level is less than or equal to 0.05) are shown in bold *italic* font.

Quiz 2	Year (J)			
Year (I)	2006	2007	2008	2009
2005	***-26.71***	***-23.57***	***-20.75***	***-30.42***
2006		*3.13*	*5.95*	*-3.71*
2007			2.82	-6.85
2008				-6.85

Table 4 shows the results of the self efficacy surveys were given to students in the course four times over the course of the semester. The results of the survey are difficult to interpret because this is the first time these particular surveys have been administered; however there is statistically significant improvement to the average scores between the first and last surveys, t (38) =-6.777, p =.000 (the notation used in this paper follows the standard format for reporting statistical results [17]). The average score increased between first and last survey by 6.8 points on a

100 point scale. This is a predictable result since the survey asks students questions that are based on course objectives. As they progress through the semester, their knowledge of the course objectives should increase.

Table 4 the results from the self efficacy tests given in 2009.

Self Efficacy 1	Average	Stn Dev
Confidence	78.11	11.51
Value	82.57	13.98
Success	80.43	11.54
Anxiety	60.37	28.12
1-Total	74.97	14.88
Self Efficacy 4		
Confidence	92.03	8.30
Value	90.39	12.57
Success	91.78	8.54
Anxiety	67.07	36.27
4-Total	85.22	14.73

Figure 2 shows a plot of critical thinking scores versus self-efficacy scores. SPSS statistical software was employed to determine if there was a correlation between critical thinking scores and self-efficacy scores. Using Pearson's correlation test, it was determined that critical thinking and self-efficacy are positively correlated. Using a 2-tailed test on 40 subjects, the correlation was significant at the p=0.05 level, r (40) =.402, p<.05, meaning that high critical thinking scores are associated with high self efficacy and vice versa.

The correlation between critical thinking and self efficacy shown in figure 2 is important because it suggests that higher self-efficacy is linked to better perfomance on critical thinking tests Although the scores are correlated, the authors cannot prove that there is a causal relationship between critical thinking and self efficacy. Despite the lack of evidence indicating that increasing self efficacy will directly increase critical thinking, professors may find it worthwhile to foster self efficacy in their students in order to help them be better students.

Figure 2 also shows that a small number of students had low self-efficacy and above average critical thinking scores. The authors looked at the breakdown of self efficacy scores for these subjects and found that they have low confidence in the objectives as well as a low ability to perform the objectives although they believe they are important to learn. This group also had high levels of anxiety about the objectives. The authors looked closer at these students and found that the majority of them are women. Only one female in the study was found to have high self efficacy. This could be a contribution as to why is it difficult to recruit and retain women in the Mechanical Engineering department. These women have high critical thinking skills, which suggests that they will do well in engineering, but they lack confidence in their ability to perform well in engineering classes. This lack of confidence could be the reason that they do not stay in the department. Since women are a minority group in engineering, they need to have a strong

sense of self efficacy in order to compete with others in the department. The authors believe that by fostering self efficacy in the women enrolled in engineering classes, more women will graduate from the program.

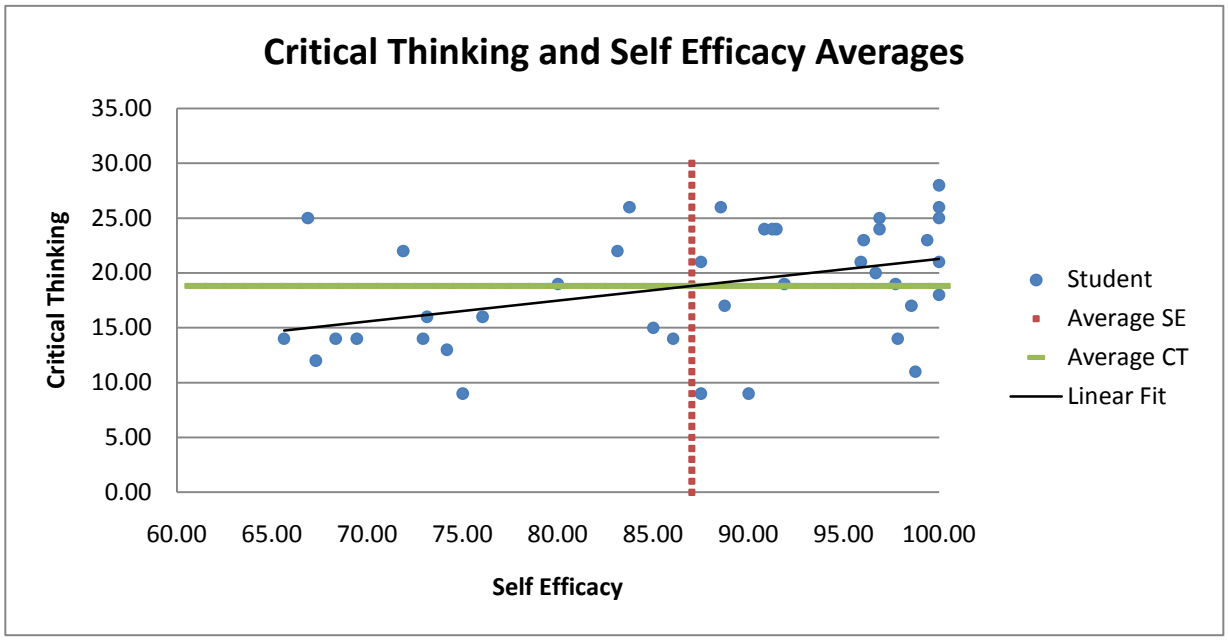


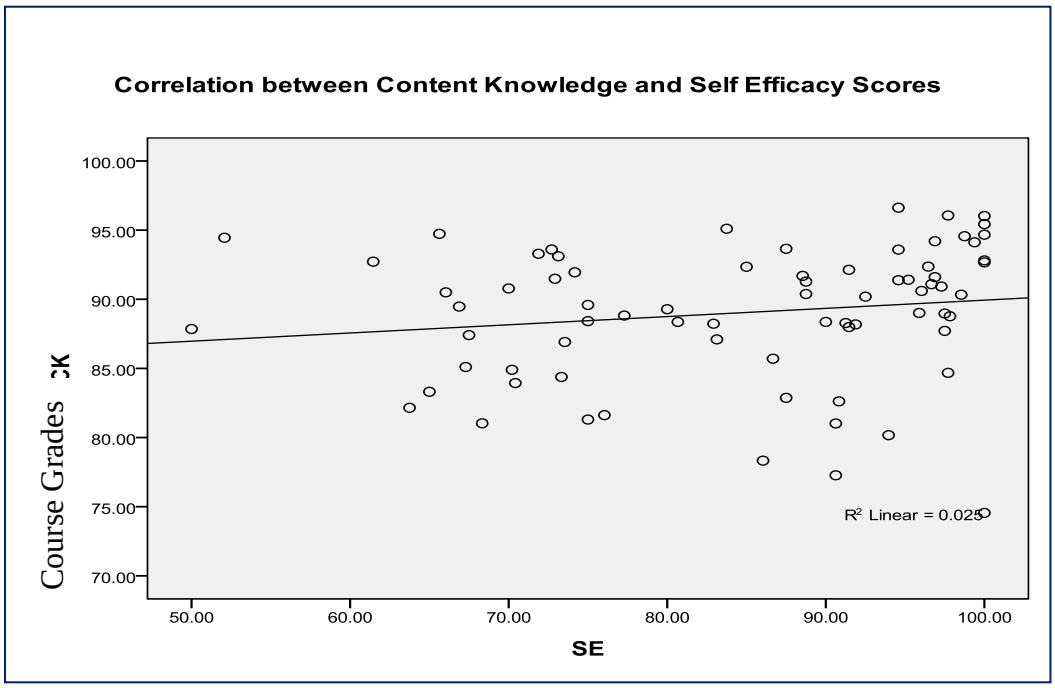
Figure 2: Scatter plot which shows the correlation between CCTST score and self efficacy results. Pearson's test results show a statistically significant positive correlation. Graph also shows the average self efficacy and critical thinking score, which are 86.3.

Opposing the subjects with high critical thinking skills and low efficacy are a small group of subjects with high self effiacy and low critical thinking level. Researchers scrutinized their self efficacy scores and found that they mostly gave the same response to each question indicating that they may not have answered the survey truthfully.

Figures 3 and 4 are plots of final grades versus critical thinking and self-efficacy scores respectively. Pearson's correlation test was also used to determine if critical thinking and self efficacy are associated with the final course grades students earned. No statistically significant correlations between either self efficacy and course grades or critical thinking and course grades were found.

Despite the correlation between self-efficacy and critical thinking, neither of these is correlated with the subjects' course grades. This is expected as course grades are often inflated or curved and not really a true measure of a student's ability. Based on the idea that the quality of a student can be determined by self efficacy, critical thinking, cognitive level, and content knowledge, researchers believe that course grades are not a good indicator of quality since neither self efficacy nor critical thinking scores correlate with grades.

Figure 3 Scatter plot relating course grades (CK) to self efficacy (SE) scores. There is not a statistically significant correlation between them.



Critical Thinking

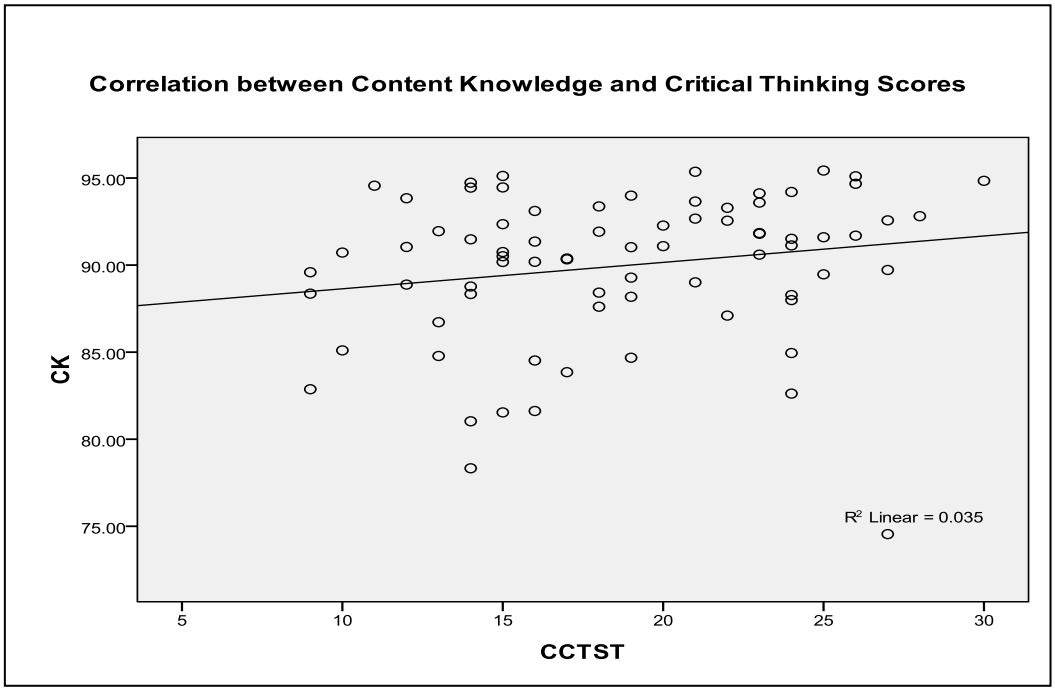


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Figure 4 Scatter plot relating course grades (CK) to critical thinking (CCTST) scores. There is not a statistically significant correlation between them.

addition to looking at the correlation between self efficacy scores, critical thinking scores, and course grades; SPSS was used to run a one way ANOVA to test for the difference in mean scores for self efficacy, critical thinking, and course grades using each student's self-reported expected

course grade as a grouping variable. Expected course grade has a statistically significant correlation with critical thinking score (F (1, 73) =5.246, p=.025), however it does not have a statistically significant correlation with self efficacy (F (1, 38) =3.237, p=.08). This result is surprising since expecting a grade seems like it should be linked to self efficacy.

Limitations

There are some limitations to this study including the validity of the self efficacy tests and a limited number of subjects. Although the self efficacy tests were constructed based on Bandura's guidelines, this is the first time they have been used in a study. Ideally, there would be a standard self efficacy test to verify the results, but that violates the nature of testing self efficacy because it would need to be general. Since self efficacy tests need to be very subject specific to what is being tested, it is difficult to validate a test.

Conclusion

Based on the data collected, several major conclusions can be drawn:

- It was found that critical thinking and self efficacy scores are positively correlated with each other, but neither is correlated with the student's course grade.
- Students who stated that they believed they would earn an 'A' in the first year course performed significantly better in critical thinking.
- Critical thinking and self efficacy scores did not have a correlation with overall course grades, which suggests that course grades may not be the best method of defining the quality of a student.
- The vast majority of female participants exhibited low self efficacy scores, which may have major implications for retention.

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