AC 2008-2854: COMPARISON BETWEEN GRADE EARNED IN A COURSE AND PERFORMANCE IN A SIMULATED FE EXAM FOR MECHANICS RELATED COURSES

Nirmala Gnanapragasam, Seattle University

Nirmala Gnanapragasam is an Associate Professor in the Department of Civil and Environmental Engineering at Seattle University. She is a geotechnical engineer and is a registered Professional Engineer in the State of Washington. She is the design coordinator of the senior capstone design program in the Civil and Environmental Engineering department, is active in consulting, in engineering education research, and in K-12 math education.

Katie Kuder, Seattle University

Prof. Kuder is Assistant Professor at Seattle University in the Dept. of Civil and Environmental Eng. She received her Ph.D. from Northwestern University. Her interests include technical writing, mechanics education and creating opportunities for undergraduate research, as well as conducting research about cement-based composites.

Dragovich Jefferey, Seattle University

Prof. Jeff Dragovich is Assistant Professor at Seattle University in the Dept. of Civil and Environmental Eng. He received his Ph.D. from the University of Illinois at Urbana-Champaign. Prior to his academic position at Seattle University, he worked as a structural engineer and is a registered Professional Civil Engineer in the State of Washington. His research interests include earthquake engineering, structural analysis methods, engineering education, and is active in consulting.

Comparison between Grade Earned in a Course and Performance in a simulated FE examination for Mechanics Related Courses

Abstract

The Fundamentals of Engineering (FE) examination is one of several assessment tools in place at universities to demonstrate some of the learning outcomes. Seattle University requires that all civil engineering graduates take the FE examination prior to graduation but does not require they pass it. Lack of student motivation to pass the examination and not knowing the questions in the FE examination may impact the assessment process. Therefore, four years ago, in 2004, the department instituted a "comprehensive examination" which simulates the FE examination. Seniors are required to take two, two-hour long comprehensive examinations, one in the fall quarter and the other in the winter quarter. The questions are purchased from an external source. The fall and winter quarter examinations simulate the morning and the afternoon portion of the FE examination, respectively. The examinations count 20% towards their final grade in the capstone design course. This paper summarizes the results compiled for the past four years for mechanics based courses. Student grades earned in specific courses are compared against their performance in related topics in the comprehensive examination. Results show that the overall student GPA in mechanics courses correlates with comprehensive examination performance. However, there is poor correlation between student performance in specific subjects and corresponding student grades. The FE pass rates of Seattle University civil engineering students have been higher than the national pass rates since the implementation of the comprehensive examination. However, more years of data is necessary to support the latter conclusion.

Introduction

ABET 2000 Criterion 3 requires that all engineering graduates demonstrate eleven program outcomes referred to as the "a-k program outcomes". In late 2005 the American Society of Civil Engineer's (ASCE) Second Edition of the Body of Knowledge Committee came up with a list of 15 outcomes. The commonality between both criteria is that engineering graduates demonstrate an ability to apply knowledge of math, science and engineering principles and ability to formulate and solve engineering problems. Fundamentals of Engineering (FE) examination, administered by National council of Examiners for Engineering and Surveying (NCEES), as the only nationally normed examination that addresses specific engineering topics has been a valuable tool to demonstrate these outcomes.

Seattle University requires that all civil engineering graduates take the FE examination prior to graduation. But it does not require that they pass it to graduate. Therefore the department felt that it may not be a suitable assessment tool to demonstrate the above mentioned outcomes due to the lack of motivation

on the part of students to pass the test for graduation. To overcome this, four years ago, in 2004, the department instituted a "comprehensive examination" which simulates the FE examination. Seniors enrolled in the year-long, capstone design course are required to take two, two-hour long comprehensive examinations, one in the fall quarter and the other in the winter quarter. The comprehensive examinations count towards 20% of the final grade in these two quarters.

The primary objective of this paper is to summarize the student performance in comprehensive examinations for the past four years for five mechanics based courses taken by all civil engineering students: statics, dynamics, mechanics of materials, fluid mechanics, and soils mechanics. Students' grades earned in the specific courses are compared against their performance in related topics in the comprehensive examinations. The secondary objective is to explore the impact of the comprehensive examination on FE pass rates before and after the implementation of the comprehensive examination.

Literature Review

Several institutions have studied the use of the FE examination as an assessment tool for student learning[1-9]. Some researchers have investigated the effectiveness of using the FE pass rate for program outcome assessment, while others have tried to correlate specific subject performance on the FE with course outcomes. Due to the difficulties in accessing data about student performance in specific subject on the FE, other institutions have implemented comprehensive exams for program outcome assessment. These in-house exams lend themselves to a more thorough analysis and can provide detailed information about student learning in specific subject areas. The results from the current approaches used to assess and improve student learning through the use of the FE and comprehensive exams are summarized below.

Several institutions have studied the use of the FE examination as an assessment tool for student learning[1-8]. Until 1993 US the Coast Guard Academy required that all cadets take the FE examination before graduation. However, the cadets were not required to pass it. A team that investigated the low pass rates found that lack of student motivation is a significant factor adversely affecting the student performance[1]. Therefore starting in 1994, taking the FE examination was made optional for cadets. This change increased the pass rate to 100% in 1994 compared to the average pass rate of 37% for the previous four years. Thirteen students chose to take the examination, as opposed to an average of 37 taking the examination in the four prior years.

University of Missouri Rolla carried out an interesting investigation on how the FE scores could be used to assess learning in various science and engineering topics[2]. The university worked with NCEES to obtain previously unreleased FE data on student performance in various topics for their institution from 1993 to

1996. Their analysis showed that there is a direct correlation between increasing FE score and increasing GPA. The correlation coefficient between the average FE raw score and average student GPA was found to be 0.42 for 104 civil engineering students over the fours years. As part of this project, the university administered a Campus Engineering Assessment (CEA) examination in April 1996, two weeks prior to the FE examination. The examination was constructed by the faculty and simulated the FE examination. The only difference being that the faculty knew the CEA questions but did not know the FE questions. Participation was voluntary and 30 students volunteered to take the CEA examination. The overall correlation between FE and CEA scores for this group of students was (r^2=) 0.74. But the correlation for individual topics was much lower. Students who volunteered to take the CEA had a 7% higher score in the morning FE than the general campus population. This could be due to the value of the practice examination or due to the nature of the volunteer group.

Lamar University has long studied how to effectively use the FE examination performance in its outcomes assessment[3,4,5]. It compared the ratio of civil engineering score of its students in a subject area with that of the national scores in the same subject. It concluded that if this ratio is one or more, it indicates that the performance of Lamar students equals or exceeds the national average. It is considering establishing this ratio be reached or exceeded for all subjects. Lamar University educators also found that all students with an overall GPA of 3.05 or higher have passed the FE examination. Furthermore it was found that students who attended review sessions and practice tests had higher pass rates and attributed this trend to higher student motivation among students choosing to review for the examination.

University of Tennessee at Martin's engineering program requires that students pass the FE examination for graduation. The pass rate was 100% at the inception of the program. However, as enrollment increased they found it difficult to maintain this success rate. To enhance the pass rate, a full, eight-hour sample test was given prior to the actual FE examination. Based on the performance of this practice test, review sessions were arranged in topics where students performed poorly. They also investigated whether student performance in courses was a good indicator of the success in the FE examination. Not surprisingly they found that students with a higher GPA were more likely to pass the FE in the first attempt. However, there were some exceptions to this rule. Furthermore, they found that students who earned a GPA of 2.0 or more in physics, calculus, statics, dynamics and strength of materials, deemed to be the core predictor of success in FE, passed the FE examination in the first attempt. Therefore, starting fall 2006 they require that students earn a minimum GPA of 2.0 in the above subjects[6].

Inter American University of PuertoRico (IAUP) has administered in-house examinations somewhat similar to that at Seattle University[7]. In the middle of the third year, students are required to take an in-house examination covering mathematics, physics and chemistry. For advanced engineering courses pre-tests

are given to assess student learning of pre-requisites. The findings are shared with instructors of basic science courses and pre-requisite engineering courses so that corrective actions could be taken immediately. The IAUP found that conducting several in-house examinations to assess student learning provided timely data for accreditation visits. Other useful FE related assessment studies are reported by the University of Texas at El Paso and by the University of New Mexico[8,9].

Seattle University and the FE Examination

As mentioned earlier, Seattle University requires that all engineering students take the FE examination prior to graduation. The importance of engineering licensing is emphasized in several classes by faculty and guest speakers. Majority of the faculty within the civil engineering department are licensed professional engineers. Although the university does not require passing the FE as a graduation requirement students have been taking the FE examination quite seriously because, a large percentage of students work for private consulting companies as interns during school as well as upon graduation and therefore recognize the importance of licensing; the students pay for the FE examination themselves.

Comprehensive Examination – Details and Setup

Seattle University's College of Science and Engineering has a year-long, industrially sponsored, senior design capstone sequence that students must take prior to graduation. A requirement of the course is that students take two, two-hour long comprehensive examinations. Details of the senior design program implementation is described elsewhere[10].

The first part of the comprehensive examination is administered in the beginning of fall quarter and simulates the morning portion of the FE examination. It consists of 60 questions. The second part of the comprehensive examination is administered within the first two weeks of the winter quarter. It simulates the afternoon portion of the subject specific FE examination and consists of 30 multiple choice questions. Table 1 summarizes the topics covered in the fall and winter quarter comprehensive examinations and the number of questions in each category.

Students are notified of the test dates, list of topics and number of questions in each topic well in advance giving them plenty of time to prepare for the examinations. The fall quarter examination is announced in the spring quarter of their junior year. The winter quarter examination is announced in the fall quarter of the senior year. Dates for both the examinations are selected so that it causes minimum disruption to the implementation of the capstone projects.

Table 1. Distribution of Topics in the Fall and Winter Quarter Comprehensive Examinations[a]

Fall Quarter Topic (no. of questions)	Winter Quarter Topic (number of questions)
Chemistry (7)	Computers & Numerical Methods (3)
Computers (4)	Environmental Engineering (5)
Dynamics (6)	Hydraulics & Hydrologic Systems (4)
Ethics (4)	Legal & Professional Aspects (2)
Fluid Mechanics (8)	Soil Mechanics & Foundation Design (4)
Mathematics (15)	Structural Analysis (4)
Statics (8)	Engineering Surveying (4)
Mechanics of Materials (8)	Water Purification & Treatment (4)

[a] Fall quarter simulates the FE morning examination; winter quarter simulates FE Civil Engineering afternoon examination

The morning section of the FE examination covers a broad array of topics outside the civil engineering discipline, including, electrical circuits, material science and thermodynamics. Similarly, the afternoon section of the FE (civil engineering) examination covers topics other than those listed in Table 1, namely, construction management, transportation and materials. However, the purpose of the comprehensive examination is to assess student learning in topics covered within the civil engineering curriculum before the comprehensive examinations are held. Therefore the department decided to narrow down the scope of the examinations to topics that are either of major importance to civil engineering or requisites completed by civil engineering majors prior to the comprehensive examination.

The faculty debated the option of writing the examination questions internally versus purchasing it from an external source. Finally, it decided to purchase the questions from an external resource, Exam Café®, as it brought in an external constituent into the assessment process[11]. Prior to the comprehensive examination, each faculty reviewed and selected the questions from the Exam Cafe® in their area of expertise. The number of questions in various topics was in the same proportion as that in the FE examination. However, the difficulty level of questions in each topic was up to the faculty selecting the questions in that area and no formal discussion took place about how faculty would select question difficulty.

The examination is administered in a setting similar to the FE examination, except for the fact that it is done on the computer rather than on a hard copy. Students are able to skip problems and return to them later, similar to paper-format exams. Current calculator policy set by NCEES is followed and FE handbooks are provided to the students.

The examination has been administered for the past four years (since fall 2004). At the inception, Exam Cafe® let the users select the questions from a selected group of topics. For example, mathematics, statics and dynamics were grouped

together, and the faculty had four different choices of group of questions from which to choose. As a result, faculty may haven been satisfied with the statics questions but unhappy with the mathematics questions, without having the option to mix and match questions from the four set of questions. However, in the summer of 2006, Exam Cafe® changed the user option such that the users could select the questions from each topic individually. Therefore, the faculty revisited their areas of expertise and prepared a new examination for the latter two years. Therefore it is worth noting here that one set of examination was administered the first two years and another set of examination was administered for the last two years.

Data Compilation

The data from the past four years of comprehensive examinations and student grades for the mechanics based courses were compiled. Transfer students from community colleges comprise half the civil engineering student population at Seattle University. These students typically transfer statics, dynamics and basic strength of materials from community colleges. In the past four years, other special cases included two students who had transferred from other four year institutions and one student who transferred from an institution outside the United States. All grades earned, irrespective of their institution where they were earned, were treated equally. Letter grades were converted to a grade point average (GPA) as follows: A = 4; A- = 3.7; B+ = 3.3; B = 3.0; B- = 2.7; C+ = 2.3; C = 2.0; C- = 1.7; D+ = 1.3; D = 1.0; D- = 0.7.

Overall Performance in the Comprehensive Examination

A summary of overall student performance in the comprehensive examination in the past four years and in the various mechanics based courses are presented in Table 2. The results are expressed as mean ± standard deviation. It is worth restating that between the first two years (2004-2005, 2005-2006) and the last two years (2006-2007, 2007-2008) the selection process and the subject ordering of questions have changed. Table 2 shows that although performance in individual mechanics courses over the past four years have a wide range from 30% to 70%, the overall performance in mechanics courses have a narrower range from 44% to 60%. With small class sizes of 18 to 22 students it is hard to determine specific trends from year to year for a single course. However, it is observed that in recent years seniors are spending long hours at well paid engineering internships and are accepting permanent employment positions prior to graduation due to the recent boom in civil engineering market and the shortage of civil engineers. Therefore, it is suspected that the lack of motivation in course work during their senior year could be contributing to the downward trend in performance in some of the courses.

Table 2. Average Performance in the Comprehensive Examinations: Overall and Subject-specific scores[a]

Academic Year (number of students)	Overall Performance		Statics	Dynamics	Mechanics of Materials	Soil Mechanics	Fluid Mechanics
	Fall	Winter					
2007-08 (n=19)	54.3 ± 9.3	47.0 ± 11.7	41.4 ± 20.0	49.1 ± 16.2	35.5 ± 15.2	46.1 ± 29.2	48 ± 20.5
2006-07 (n=22)	55.8 ± 9.8	43.5 ± 12.2	50.0 ± 20.8	46.2 ± 17.8	40.9 ± 16.0	48.9 ± 27.3	40.3 ± 17.2
2005-06 (n=22)	59.7 ± 14.4	51.7 ± 8.3	69.3 ± 24.6	56.1 ± 28.0	50.0 ± 29.1	42.0 ± 26.0	30.0 ± 10.7
2004-05 (n=18)	58.6 ± 13.7	53.9 ± 13.4	66.0 ± 28.1	61.1 ± 29.7	52.1 ± 22.4	55.9 ± 25.8	35.4 ± 14.4

[a] All scores expressed as Mean ± Std. deviation

Figure 1 shows the average comprehensive examination score versus average student GPA for the five mechanics based courses (ie. course grades for dynamics, fluid mechanics, soil mechanics, statics and strength of materials have been averaged) for the past four years. The correlation coefficient (r^2) for the data is 0.44 with 81 data points. This shows that there is a direct correlation between average student grade in mechanics courses and performance in the mechanics portion of the comprehensive examination. This is comparable to the correlation coefficient reported in the University of Missouri-Rolla study[2].

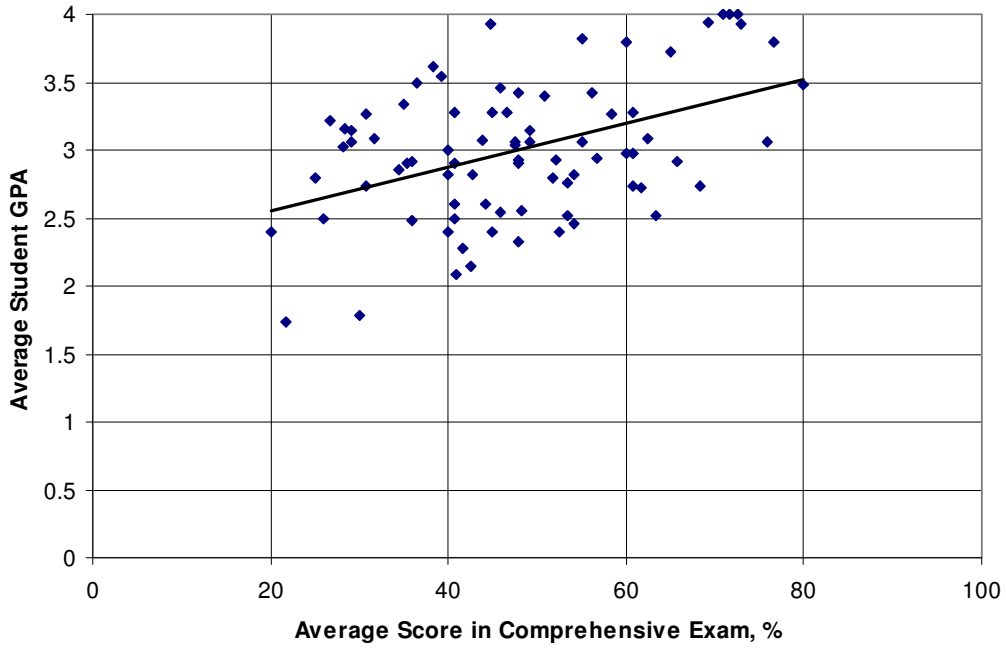

Figure 1. Average Comprehensive Examination Score versus Average Student GPA for the Past Four Year for the Mechanics Based Courses

Performance in Specific Courses

Figures 2 through 6 show the relationship between the comprehensive examination score and student GPA for statics, dynamics, mechanics of materials, soils mechanics and fluid mechanics for the past four years, respectively. The student grades in specific courses are converted to a GPA as described previously. Figures 2 through 6 show no clear trend between course grade and performance in the comprehensive exam. Small class sizes from one year to another, ranging from 18 to 22 students, and the limited number of questions in each topic in the comprehensive examination make year to year interpretation more difficult.

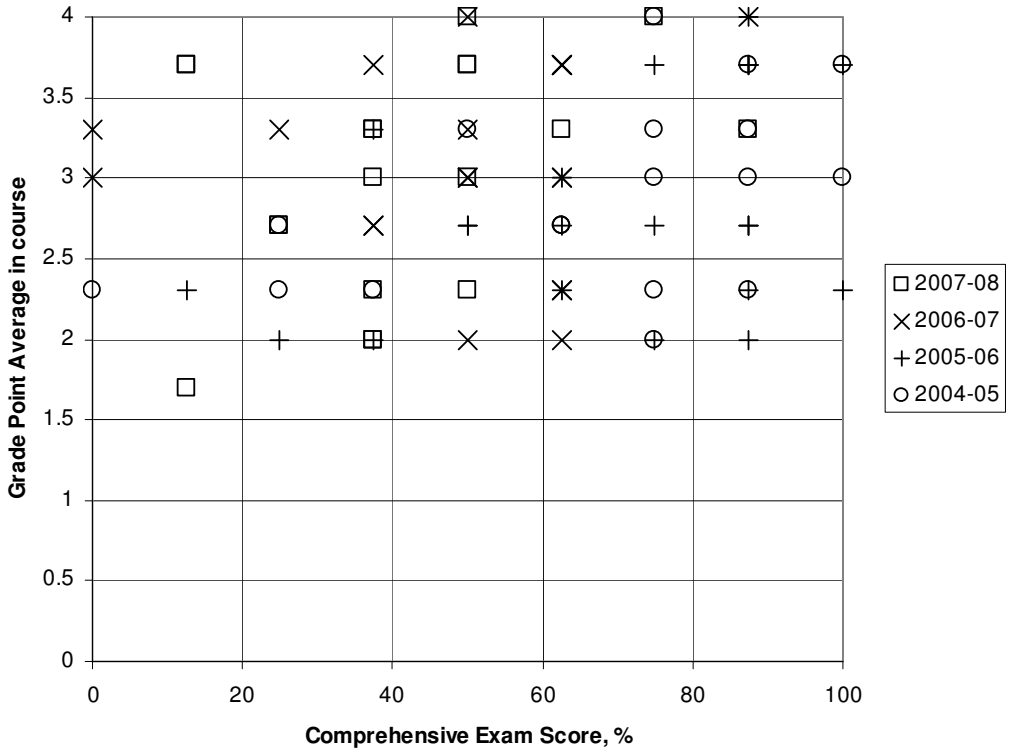

Figure 2. Comprehensive Examination Score vs. GPA in Statics

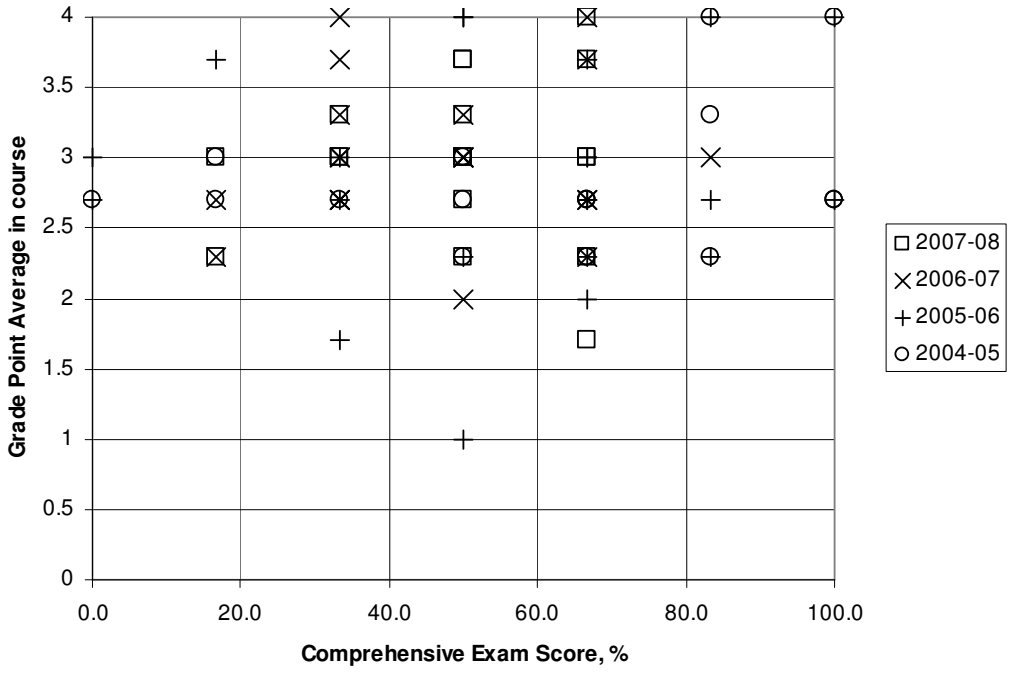

Figure 3. Comprehensive Examination Score vs. GPA in Dynamics

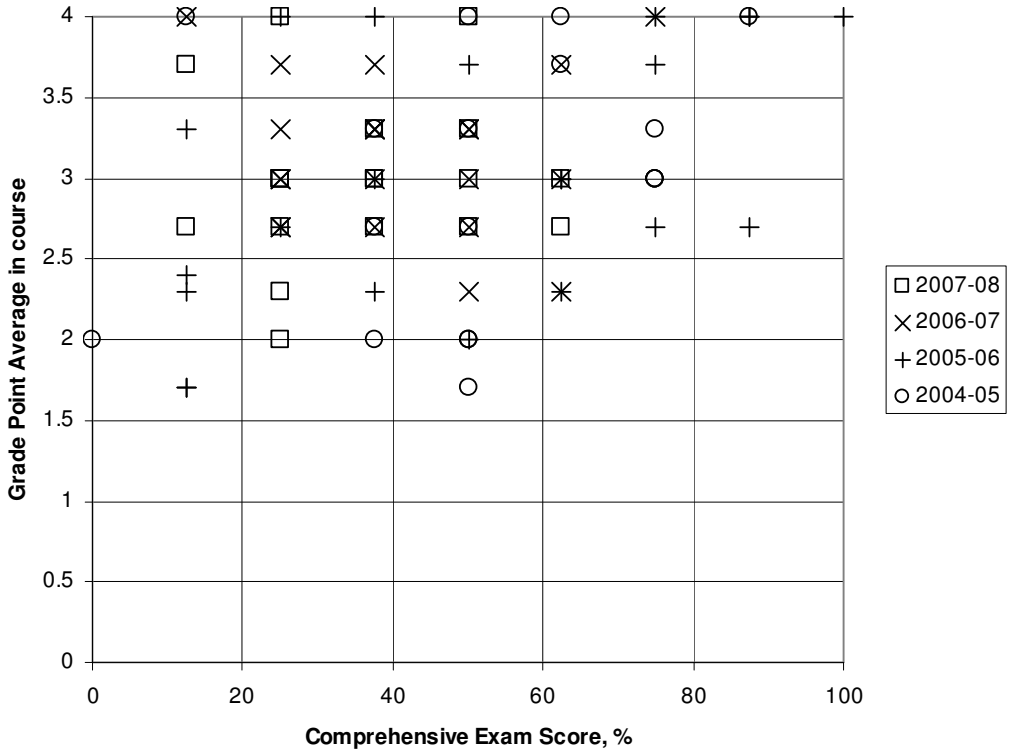

Figure 4. Comprehensive Examination Score vs. GPA in Mechanics of Materials

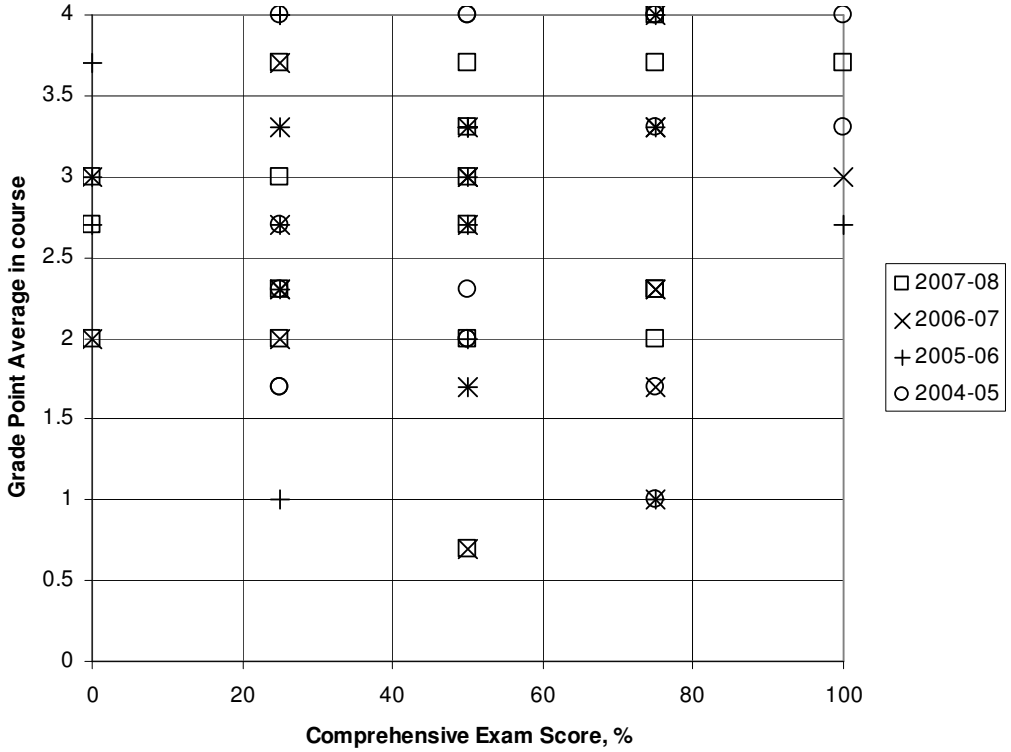

Figure 5. Comprehensive Examination Score vs. GPA in Soil Mechanics

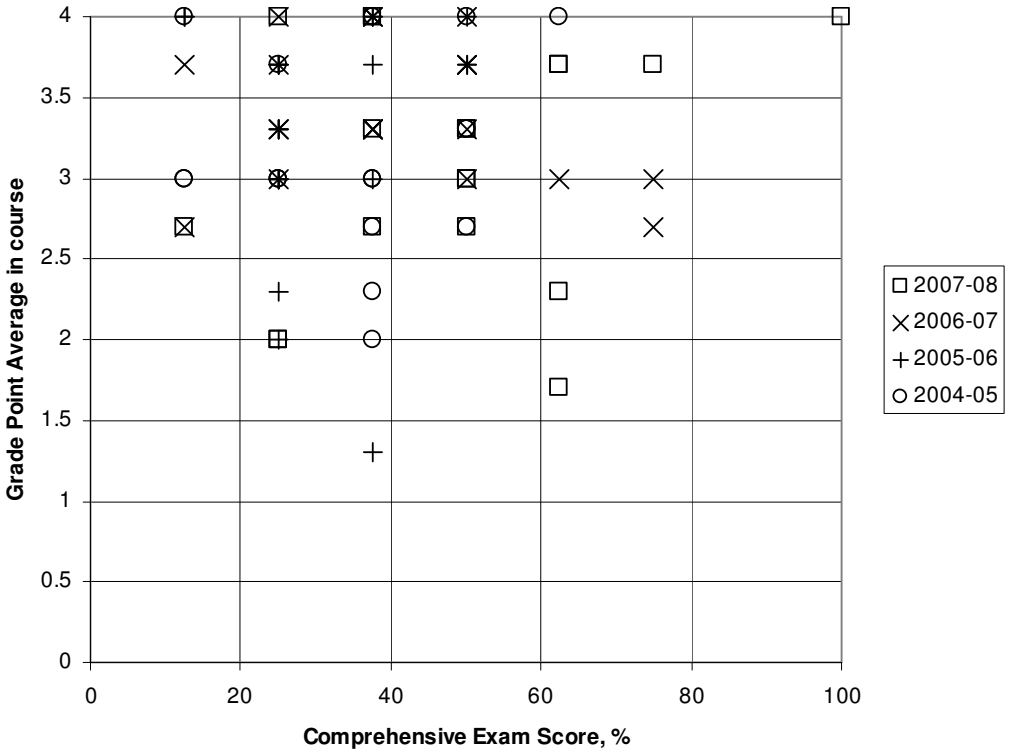

Figure 6. Comprehensive Examination Score vs. GPA in Fluid Mechanics

Table 3 shows the correlation coefficient (r^2) for the five courses for the past four years. The correlation coefficients are not reported for each subject on a yearly basis because of the small class size each year.

Table 3. Correlation Coefficient between Student Performance in the Comprehensive Examination and Student GPA in Courses for the Four Years

Subject	Correlation Coefficient
Statics	0.21
Dynamics	0.10
Mechanics of Materials	0.29
Soil Mechanics	0.09
Fluid Mechanics	0.05

In general, there is very low correlation between comprehensive examination score and student GPA for the five courses. However, it is interesting to note that higher correlation coefficients are observed for statics and mechanics of materials. One reason for this trend could be that these courses are precursors for upper division courses. As a result, the concepts are reinforced in upper division classes, giving the students better knowledge of the material.

Nevertheless, a number of factors may have affected the student performance in individual subjects making it difficult to draw definite conclusions:

1) Question Selection Process – As discussed previously, different faculty selected the questions for each section based on their own area of expertise. However, no discussion was given as to the range of question difficulty. Therefore, it is possible that certain faculty could tend to select more challenging questions and, as a result, certain subject areas could be more difficult. Currrently, Exam Cafe® does not rate question difficulty, so a direct analysis cannot be done. However, in the future, faculty will discuss this issue and attempt to make the range of question difficulty more uniform.

2) Problem Ordering – Informal discussions with the seniors after the comprehensive examination has suggested that they get tired towards the end of the examination and could, as a result, perform poorly on later questions. Over the past four years, the order in which the subject-specific questions have been posed has been varied. Future work should include a more thorough analysis of this issue.

3) Computer examination format – The comprehensive examination is given electronically. Students are generally used to paper-format examinations. Electronic examinations require students to transfer their work between the computer and paper; however it does allow them to skip problems and return to them later, similar to paper-format exams. It is unclear how the change in format could affect performance. Students that perform well in the classroom could be more effective at paper format.

4) Student preparedness – The amount of effort that students put into preparing for the examination is difficult to assess. Stronger students may not feel the need to study for the examination because they are confident in their ability to pass the FE. Some students may expect their performance in the senior design course to be strong enough to counteract the impact of the 20% grade weighting given to the comprehensive examination. Finally, students may only study for the comprehensive examination if near to when they plan on taking the FE examination. Therefore, some students could prepare only in the fall, whereas others prepare only in the spring. Starting winter 2008, the authors have begun administering a questionnaire to the students to determine student preparedness prior to the comprehensive examination and the FE. The results will be analyzed for future work.

Effect of Comprehensive Examination on FE Pass Rates

In order to see whether the implementation of the comprehensive examination has improved the student performance in the FE examination, Seattle University civil engineering FE pass rates were compared against the national averages for the passed few years. Table 4 shows the findings. National pass rates reported are

for first-time examinees from EAC/ABET accredited institutions who have declared civil engineering as their major. Although Table 4 shows an improvement in the FE pass rate since the inception of the comprehensive examination, including pass rates higher than the national averages, more years of data is necessary to establish a more conclusive trend especially considering the small class sizes.

Table 4. Seattle University and National Averages of FE Examination Pass Rate for Civil Engineering Discipline

Academic Year	Average FE Examination Pass Rate, %	
	Seattle University -CEE (no.of examinees)	National CEE
2006 -2007	76 (21)	72
2005 - 2006	79 (19)	71
2004 – 2005	87 (15)	78
2003 – 2004	73 (15)	81
2002 - 2003	80 (15)	81

Summary and Conclusions

Seattle University has been administering an internal comprehensive examination to its civil engineering seniors for the past four years. The comprehensive examination is given in two parts: one in fall quarter and the other in winter quarter. The fall and winter examinations simulate the morning and discipline specific, afternoon portion of the FE examination, respectively. The questions are purchased from an external source, the Exam Café®. The comprehensive examination score is counted for 20% of the student grade in the senior capstone project each quarter.

The following conclusions can be drawn from the analysis of the data compiled over the past four years on student performance in the comprehensive examination and in each of the five mechanics based courses: statics, dynamics, mechanics of materials, soil mechanics and fluid mechanics.

- There is direct correlation between increasing student GPA and student performance in the comprehensive examination for mechanics based courses. A correlation coefficient of 0.44 was obtained for a total of 81 students.

- There is very low correlation between scores in individual mechanics topics in the comprehensive examination and student GPA in the specific courses. However, statics and strength of materials exhibited relatively higher correlation coefficients possibly because many of the advanced mechanics courses reinforce the concepts learned in these two basic courses.

Although the Seattle University civil engineering FE pass rates are higher than the national FE (civil) pass rate since the implementation of the comprehensive examination, more years of data is needed to support this conclusion.

References

1. Mazurek D.F (1995). "Consideration of FE Exam for Program Assessment", Journal of Professional Issues in Engineering Education and Practice, 121(4), 247-249.

2. Watson J.L (1998)."An Analysis of the value of FE Examination for the Assessment of Student Learning in Engineering and Science Topics", Journal of Engineering Education, 87(3), 305-311.

3. Koehn E, Mandalika R (2005). "Curriculum Outcome Assessment using Subject Matter on the FE Examination", Proceedings of the 2005 American Society of Engineering Education Annual Conference and Exposition.

4. Koehn E, (1989). "Fundamentals of Engineering (FE) Examination: motivation/review enhances pass rate", Journal of Professional Issues in Engineering, 115(3), 289-296.

5. Koehn E., Malani R.D. (2005). "Review for and Assessment of the Fundamentals of Engineering Exam", Proceedings of the 2005 American Society of Engineering Education Annual Conference and Exposition.

6. Helgeson R, Wheeler E. (2006). "Passing the Fundamentals of Engineering Examination as a Graduation Requirement in a General Engineering Program: Lessons Learned", Proceedings of the 2006 American Society of Engineering Education Annual Conference and Exposition.

7. Withington J.P. (1999). "Short Cycle Assessment Techniques for ABET Criteria 2000 Compliance", 29th ASEE/IEEE Frontiers in Education Conference, San Juan Puerto Rico, Session 11b1.

8. Wicker R.B, Quintana R. Tarquin A. (1999). "Evaluation Model using Fundamentals of Engineering Examination", Journal of Professional Issues in Engineering Education and Practice, 125(2), 47-55.

9. Nirmalakhandan N., Daniel D, White K, (2004). "Use of Subject-Specific FE Exam results in Outcomes Assessment, Journal of Engineering Education, 93(1), 73-77.

10. Nirmala Gnanapragasam. "Industrially Sponsored Senior Design Program: Implementation and Assessment", ASCE - Journal of Professional Issues in Engineering Education and Practice, accepted for publication.

11. Exam Café Website. http://ppi2pass.com/ppi/ECMain, (January 8, 2008).