Correlation between the Course Knowledge Survey Results and Student Performance in a Civil Engineering Course

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Introduction

A commonly accepted assessment instrument used for both diagnostic and formative purposes is the concept inventory, which refers to any kind of research-based assessment technique that measures conceptual understanding in a subject [(1)]. The usage of concept inventory helps the instructors to measure their teaching effectiveness and determines if students have adequate understanding of important concepts at the end of the semester. Previous studies proved that concept inventories provide reliable data and can positively influence pedagogical practices [(2)]. When the same set of questions are used, concept inventories allow for an evaluation of students' pre-course and post-course knowledge on a subject effectively. The pre-test helps to establish and evaluate the prior knowledge on a subject, and the post-test measures the knowledge gained over the entire course. These types of tests also help to distinguish learning and performance [(3)].

In most introductory level soil mechanics courses, too much emphasis is placed on calculation methods without emphasizing concepts and principles. In addition, most junior civil engineering students take the introductory soil mechanics course with almost no prior knowledge in soils or geology [(4)]. To assess the amount of exposure the students have in soil mechanics prior to their first course in soil mechanics, a background knowledge probe survey was developed for an undergraduate level soil mechanics course as part of a multi-institutional study. The initial study was carried out in four institutions with civil engineering programs, three of which are predominantly undergraduate institutions, and one was a large research institution. The pre-test was administered in the Soil Mechanics and Soil Behavior course (CE 338) at the University of Evansville to measure students' prior soil related knowledge and to identify student misconceptions at the beginning of the semester. The same short-answer test (post-test) was given on the last day of the semester to assess the knowledge gained over the course of the semester. This study made attempts to assess the knowledge gained in the conceptual understanding of the materials covered. From this study it was concluded that the students are entering the introductory soil mechanics course with little or no prior knowledge from other courses, internships, or co-op experiences. The results showed that there are variations in students' exposure to soil related concepts at various institutions. The pre-test performance of students was low, as students are not expected to have exposure to the concepts prior to completing a course in soil mechanics. This research provided a necessary first step towards identifying capabilities and limitations in teaching soil mechanics and provided useful data on ways to improve their understanding of fundamental concepts [(4)]. However, there have been no effort taken in any of the studies to see if the pre- and post- test performance has any correlation to overall student performance in their courses. In this paper, an effort was made to correlate the relationship between the concept inventory scores (pre and post) and student performance that were assessed through the final grade earned and their overall performance in the Fundamentals of Engineering (FE) exam in geotechnical engineering.

Assessment Instrument

A concept inventory (pre and post test) with ten questions was developed for an introductory level soil mechanics course as a part of the original study [4]. The questions used for this study are given in Table 1. The pre-test was administered to measure students' prior knowledge on soils and to identify student misconceptions on the first day of class. The same test was administered on the last day of the semester to assess the knowledge gained. Neither the pre-test nor post-test was counted towards the course grade and the participation in these tests were voluntary. Students were encouraged to complete all ten questions to the best of their abilities during the pre-test.

Table 1. The pre and post-test survey questions [4]

Question #	Questions	Geotechnical concepts assessed
1	What are some of engineering characteristics of fine-grained soils?	Engineering characteristics of fine-grained soils
2	What does high relative density and low void ratio indicate?	Interpretation of index properties of soils
3	Why do we need to assess the shear strength of soil?	Significance of assessing shear strength
4	What is the difference between compaction and consolidation?	Compaction vs. consolidation
5	Why do we compact soils in earthwork?	Significance of compaction
6	Why is determination of water content of soil important?	Significance of water content
7	What causes settlement in soils (i.e., sources of settlement in soils)?	Sources of settlement in soils
8	What is the difference between normally consolidated and over-consolidated clay?	Prediction of consolidation settlement
9	What is difference between the drained condition and undrained condition?	Determination of shear strength / water flow through soils
10	The major and minor principal stresses at a certain point in the ground are 450 and 200 kPa, respectively. Determine the maximum shear stress at this point.	Interpretation of Mohr circle of stresses

Study Methodology

In the civil engineering program at the University of Evansville, the pre-test (as seen in Table 1) was administered to junior civil engineering students on the first day of Soil Mechanics and Soil Behavior (CE 338) course to measure their prior knowledge on soil mechanics concepts gained through other related courses, internship, and co-op experiences during Spring 2015, 2017, 2019, and 2021. The same short-answer test was administered on the last day of the semester to assess the knowledge gained. This resulted in a total sample size of 52 responses as shown in Table 2. Each correct answer was awarded one point and partially correct answers received 50% of the point. It is to be noted that most answers for these questions are qualitative and can have many possible answers except the last question that involves calculation.

Table 2. Survey Sample Size Information

Survey Year	Sample Size
Spring 2015	13
Spring 2017	17
Spring 2019	14
Spring 2021	8
Total	52

Throughout the semester, the students learnt different soil mechanics concepts that were tested on the concept inventory test (pre and post). As seen from Table 3, all test topics were taught in this course with varying amount of coverage. The topic coverage percentage and the number of test questions from the topic had no relation. For example, the compaction topic needed three class periods and had three questions in the concept inventory test; however, the index properties and soil classifications required seven classes and had only one question in the assessment test.

Table 3. Course Coverage and Assessment Questions

Curricular Topic	Class Hours Devoted	Topic Coverage, %	Test Question Number(s)
Geology	2	5	-
Index Properties and Classifications	7	18	1
Phase Relations	4	10	2
Compaction	3	8	4, 5, 6
Permeability	4	10	-
Seepage/flow nets	3	8	-
Stresses in soils	6	15	10
Settlement	5	13	4, 7, 8
Shear Strength of soils	4	10	3, 9
Case Studies	1	3	-

The post-test results were individually compared to student's final exam performance to study if the knowledge survey results have any correlation with the final grades. Efforts were also made to correlate the post-test performance average of the cohorts with their FE exam performance in geotechnical engineering area.

Results

The post and pretest scores of each student were compared with the final grade point earned. While assigning the grade point, the university recommended scale was used corresponding to the letter grade (A=4.0, A-=3.7, B+=3.3, B=3, B-=2.7, C+=2.3, C=2.0, C-=1.7, D+=1.3, D=1.0, F=0). To be able to correlate the pre and post test scores the grades were converted to a scale of 10, by multiplying the earned grade point earned by a factor of 2.5. The data collected over the study period is given in Table 4.

Table 4. Data Collected for This Study

Semester	Student #	Pre-Test Total	Post-Test Total	Difference	Grade Point Earned	Adjusted Grade Point
Spring 2015	1	1.5	5.5	4	1	2.5
	2	1.5	7	5.5	3.3	8.25
	3	2.5	8	5.5	3.7	9.25
	4	1	4.5	3.5	2.7	6.75
	5	3	7	4	4	10
	6	1	4.5	3.5	3	7.5
	7	0	5.5	5.5	1.7	4.25
	8	4.5	8.5	4	3	7.5
	9	0.5	3.5	3	1	2.5
	10	3	7.5	4.5	3.3	8.25
	11	0.5	4.5	4	3.3	8.25
	12	2.5	6	3.5	1.7	4.25
	13	1	8	7	1	2.5
Spring 2017	14	4	8.5	4.5	2	5
	15	0.5	6	5.5	3	7.5
	16	2.5	5.5	3	3	7.5
	17	7	8.5	1.5	4	10
	18	6.5	7.5	1	3	7.5
	19	0	3.5	3.5	2.7	6.75
	20	1	7	6	2.7	6.75
	21	2	3	1	2	5
	22	4.5	6	1.5	1.7	4.25
	23	3	6	3	4	10
	24	1	6	5	3	7.5
	25	4	8	4	4	10

	26	6.5	9	2.5	1.7	4.25
	27	0.5	1	0.5	3.3	8.25
	28	2.5	7.5	5	3.7	9.25
	29	3.5	7.5	4	3.3	8.25
	30	4.5	8.5	4	1	2.5
Spring 2019	31	4	8.5	4.5	3.7	9.25
	32	2	5	3	2	5
	33	3.5	5.5	2	2.7	6.75
	34	6	8	2	3	7.5
	35	3	7	4	3	7.5
	36	3.5	7.5	4	3.7	9.25
	37	4	7.5	3.5	3.7	9.25
	38	2	6.5	4.5	4	10
	39	2	3.5	1.5	0	0
	40	5	8	3	3.7	9.25
	41	3	4.5	1.5	0	0
	42	5.5	8.5	3	4	10
	43	2.5	6.5	4	3	7.5
	44	5.5	7	1.5	3.7	9.25
Spring 2021	45	2.5	7.5	5	2.7	6.75
	46	5	9	4	4	10
	47	4	7	3	2	5
	48	3.5	8	4.5	3.3	8.25
	49	2	7	5	3	7.5
	50	2.5	5.5	3	1	2.5
	51	5.5	7.5	2	3.7	9.25
	52	3	7.5	4.5	3	7.5

Analysis

The collected data was plotted to study the relationship between student performance in the concept inventory tests and their overall course performance, between the pre, post and improvement (difference) scores against the adjusted grade point.

As can be seen from Figure 1 and the data given in Table 4, two students received zero points in the pre-test and few students received less than 3.0. This is rather a very low score because each question had many possible answers and some of the questions were not highly technical. This shows that some students did not take this concept inventory test very seriously. There is no correlation between the pre-test results and course performance of students.

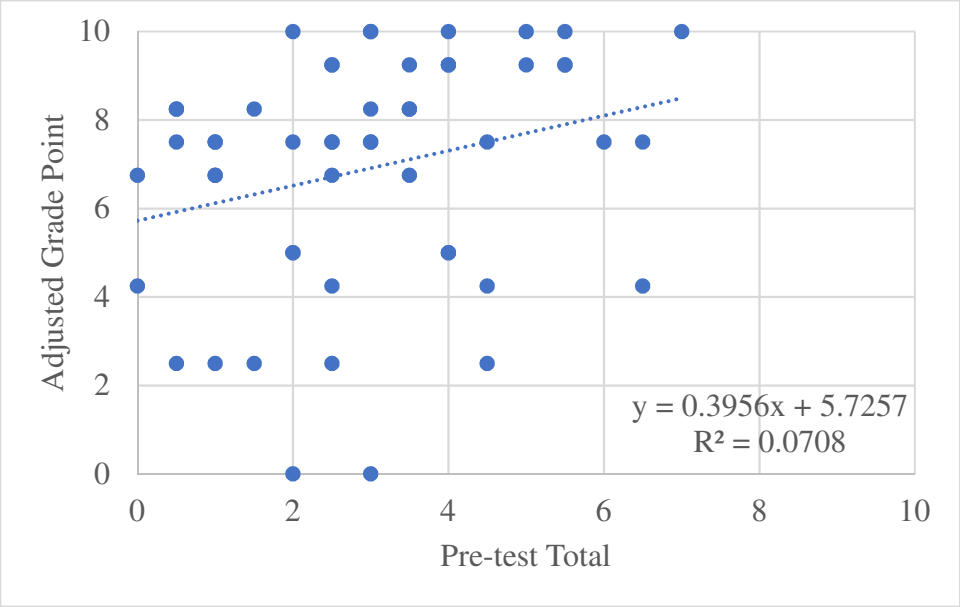

Figure 1. Relationship between Pre-test Total and Adjusted Grade Point

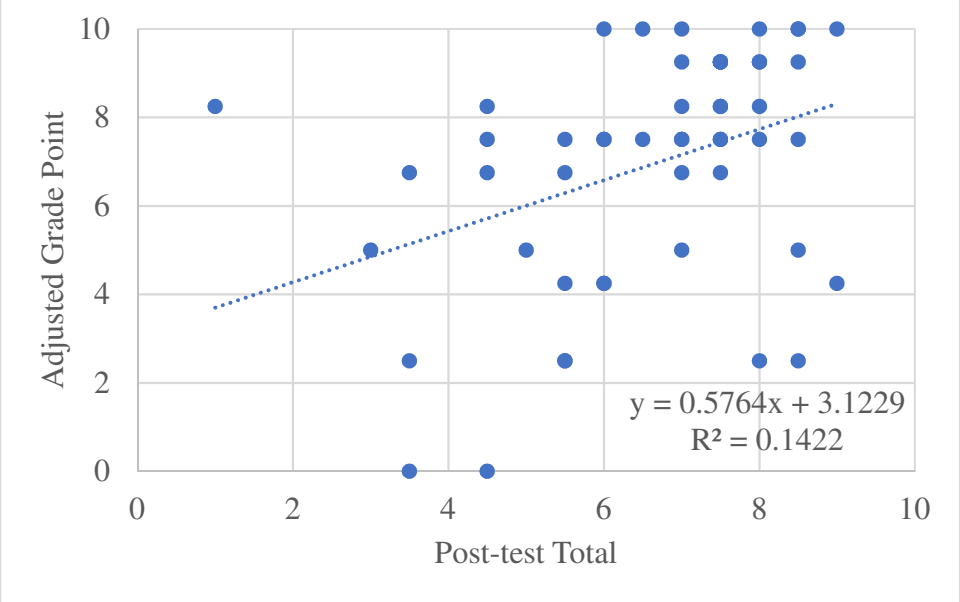

Figure 2. Relationship between Post-test Total and Adjusted Grade Point

A much better correlation was obtained between the post-test scores and student performance. Few students performed well in the post-test but did not receive a good grade in the course and two of them received a failing grade (F). If the outliers are removed, it may provide a better correlation. Many students, who did very well in the course, did not perform to that performance level in the post-test. This goes back to the same issue of students not taking this voluntary assessment test seriously.

The difference between the pre and post scores (improvement score) and the student overall performance was plotted to study the relationship. From Figure 3, there is no correlation (R^2=0.02), and the data has a large scatter.

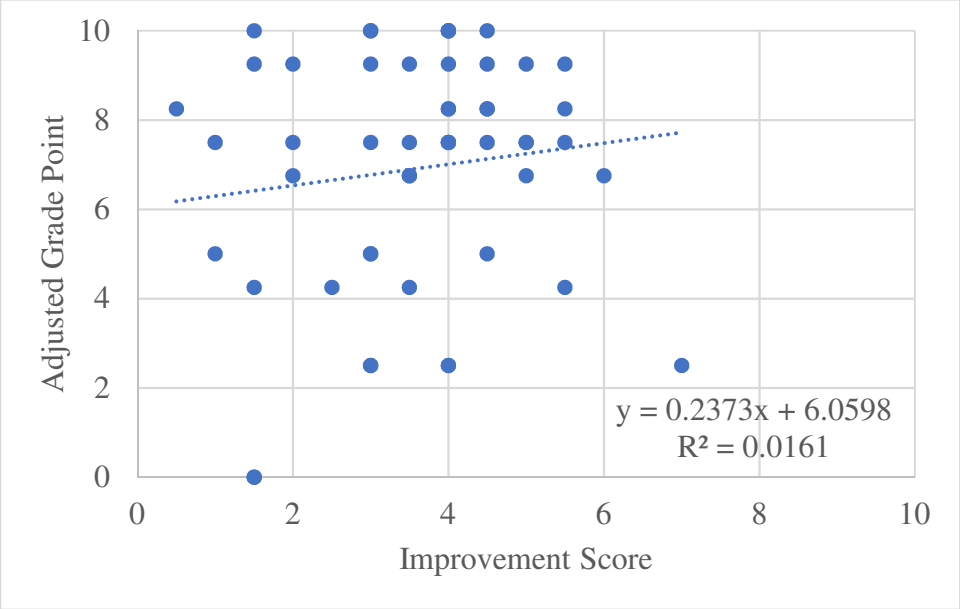

Figure 3. Relationship between Improvement Score and Adjusted Grade Point

Since there is no distinct relation between the concept inventory scores and overall course performance, the average post-test total for the cohorts were compared with their FE exam cohort performance for spring 2015 (2016 FE results), spring 2017 (2018 FE Results), and spring 2019 (2020 FE Results) groups. For the 2021 cohort, the FE results are not available currently. While looking at the cohort average in the post-test and FE scores, there is no correlation between them. However, more data is needed to verify this relationship.

Table 5: Post Test Average Scores and FE Performance

	Post-Test Average Score	UE FE Performance in Geotechnical Area (%)
Spring 2015 Cohort	6.2	74
Spring 2017 Cohort	6.4	67
Spring 2019 Cohort	6.7	66
Spring 2021 Cohort	7.4	Not Available

Conclusions and Recommendations

While comparing the results of concept inventory tests (pre and post-tests) with the overall course and FE exam performances, there are no correlations between them. This could be a result of pre-and post-test data being completed in the classroom as voluntary. A vast majority of students do not take this pre and post-tests very seriously since they are not part of the course grade. This might have affected the data gathered through the concept inventory tests.

The other reason could be the way student performance is evaluated in the soil mechanics course. The exams, homework, and quizzes that are part of the course grade are predominantly based on calculations and the use of proper equations rather than conceptual understanding. This could be one of the reasons for the lack of relationship between the assessment scores and overall course performance.

Since it was announced to the students while taking the exam that multiple answers are possible for most questions, it might have confused the students and they could have had difficulty in answering the questions. Instead of having open-ended questions, it is suggested to have multiple-choice format to make the process easy and have consistency while grading their responses. The bias and precision in grading could have resulted in an inaccurate evaluation of the assessment responses as proved recently by Ghanat et al [(5)]. More data could be included in the future and this study can be analyzed with similar approach in other institutions to see if there is a relationship between the concept inventory tests and student performance.

References

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