Work In Progress: Combining Concept Inventories with Rapid Feedback to Enhance Learning

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Abstract - **In this project our goal is to adapt the Concept Inventory for frequent classroom use, and to implement it in a system to provide rapid feedback to students of their understanding of key concepts being presented. The feedback system acts as the focal point and catalyst to encourage students, working in pairs, to assist each other in correcting misconceptions or deepening each other's understanding of the topic at hand. Furthermore, the system allows the professor to assess the students' level of comprehension (or misconception) in a just-in-time fashion, and thus guides his or her pacing and coverage of the material. The rapid feedback is enabled through wireless-networked handheld computers. In this first year of the study, we have implemented the system in a lower-level, core-engineering course (engineering mechanics: statics). This paper will focus on the motivation for and the design of this project; our presentation will describe results from the first implementation.**

Index Terms – Concept inventory, Concepts learning, Personal digital assistants, Rapid feedback, Statics, Wireless computers

INTRODUCTION

Core engineering courses, such as the mechanics sequence and thermodynamics, are comprised of key concepts that students need to master in order to succeed in follow-on courses. Students must *comprehend* these concepts at sufficient depth (as opposed to rote memorization of procedure) and *transfer* this understanding to other courses and contexts. In this project, our hypothesis is that such learning is achieved in an active, peer-assisted environment in which the students are provided frequent and rapid feedback of their state of understanding.

BACKGROUND AND MOTIVATION

Bransford et al. [1] point out that "effective learning is its durability and transferability," which means having a long-term impact on how it influences other kinds of learning or its application in other contexts. Furthermore, they state: "Learning must be guided by generalized principles (concepts) that are widely applicable. Knowledge learned at the level of rote memorization of rules and algorithms inhibit transfer and limit durability. Learners are helped in their independent learning attempts if they have conceptual knowledge."

Concepts Inventory (CI) was originally devised in the physics education community for diagnosing and addressing student misconceptions in Newtonian mechanics [2, 3, 4]. The physics CI, called Force Concepts Inventory (FCI), contains 30 multiple-choice questions. All of the questions in the FCI require little or no calculation to arrive at the solution, which minimizes the students' tendency to use rules and formulas.

The supporting rationale for developing and using the FCI is perhaps best given by Stewart and Hafner [5]: "Producing a correct answer does not necessarily mean that the student understands the underlying concepts. Both correct and incorrect answers can be obtained by the application of algorithms without such understanding. All that is required is 'procedural knowledge.'"

We contend that Concepts Inventories are appropriate for core engineering courses, where understanding of concepts is just as important as calculations-based understanding since follow-on courses (courses for which the core courses are prerequisites) build on these concepts. Furthermore, we believe that understanding of concepts in lower level courses will lead to better performance on calculation-based problems.

Providing feedback to students of their current level of understanding of concepts is critical for effective learning. It is also important for the professor. This feedback is typically accomplished with homework sets, quizzes and tests. All of these techniques, however, suffer the faults of being too slow, too late, and too tedious to apply frequently.

Freeman and McKenzie [6] discuss several issues that inhibit better student learning in higher education. For students, there is a lack of individual feedback on learning; few opportunities for dialogue to improve learning; and a feeling that the subject is impersonal. From the faculty members' perspective, the difficulties lie in knowing what students are really learning, providing individualized feedback, addressing students' specific misconceptions, attending to diverse learning styles, and engaging students in learning.

Bransford et al. [1] state: "Learners are most successful if they are mindful of themselves as learners and thinkers. In order for learners to gain insight into their learning and their understanding, frequent feedback is critical: Students need to monitor their learning and actively evaluate their strategies and their current levels of understanding." Our project addresses all of these issues by providing them with timely feedback and opportunities to improve concept learning.

PROJECT IMPLEMENTATION

To achieve our goal to adapt Concept Inventories and integrate them with rapid feedback and peer-assisted learning, we developed a system that includes handheld personal digital assistants (PDAs) for the students to provide responses to concept questions posed by the professor from a laptop computer. Both the PDAs and the computer run software designed to (1) pose the concept questions from the computer through a projector, (2) send (by the students) and gather (by the professor) the responses to each question, and (3) analyze and display the pooled results to the students and professor. Thereafter, depending on the results, the professor will choose to either (a) lecture more on the current concept before posing another question on the same concept, or (b) give the student teams time to discuss the concept before posting their answer to the same or a different question, or (c) move on to the next topic to be covered in the course. In the first year of this project, we implemented this system in two sections of Engineering Statics in the fall 2003 semester.

Statics is the first mechanics course for mechanical, civil and electrical engineering students at Rowan and many other engineering schools. It is also typically the first engineering course that students encounter in their academic career. Unfortunately, statics is well known to be a course in which students are 'weeded' out, since poor performance often discourages students from continuing to pursue engineering as a career track.

Statics is challenging for a variety of reasons, including the realities of the rapid pace of the materials presented, the steady succession of homework sets and the self-discipline required to complete them, and challenging concepts that continually build upon one another in increasing complexity. It is precisely for the latter reason that we chose to extensively test our system in this course. We believe that misconceptions lead to further misconceptions as the course progresses. Thus, it is crucial to diagnose these problems and correct them as soon as they occur. In statics, students' grasp of the concepts involved is much more valuable than their performance on calculation-based problems, especially given the need for the learned concepts to be durable and transferable to future courses.

PROJECT STATUS

This project was implemented in two sections of statics in the fall 2003 semester. We are currently analyzing the results and will present preliminary findings in our presentation.

Two methods of providing feedback to the students were employed in a cross-over design of experiment. One method was the PDA-enabled one described earlier, and the other utilized flashcards, similar to the technique used by Mehta [7]. Other than the method of providing feedback to the students and professor, the materials covered and the assignments, quizzes and examinations were identical.

A cross-over design of experiment is intended to eliminate confounding factors that cannot be controlled for using multiple-regression analysis. For example, the students may not be randomly assigned to each of the two course sections, or the time at which each section is held may affect student performance.

In a cross-over design, one of two study groups (course sections in this case) is randomly chosen to receive instruction with the PDA-enabled system while the other group uses the flashcard system for a fixed period of time. For the next period, one group is again randomly assigned one feedback method while the other group receives the opposite 'treatment.' In this manner, each section acts as its own control to eliminate the non-correctible confounders.

We used a bi-weekly period of treatment as a compromise between too many potential switches (weekly) and possible adverse effects on attitude due to change after a longer period. Analysis of variance was used to test for the presence of any treatment effect and quantify the performance gains.

The performance of the two fall-2003 cohorts will be compared to each other as well as to a fall-2002 control group. Performance will be measured by the observed mean scores for each quiz and examination administered to the three groups. In order to control for the effects of other variables (or covariates) that might affect the response variable (the mean scores), analysis of covariance will be employed. These covariates include, for example, the students' previous grade in calculus, or their performance in Physics I.

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