Using Networked Tools to Enhance Student Success Rates in Large Classes[1]

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Abstract *- A two-year project to study and assess the use of technology to enhance student learning and performance is described. Preliminary results are encouraging and will serve to guide future direction of the project.*

Introduction

A project has been initiated to assess the degree to which use of technological tools can enhance student success in a 500-student calculus-based physics course for engineers. The tools consist of an Asynchronous Learning Network (ALN) for student assistance and of a networked software system to implement a Computer-Assisted Personalized Approach (CAPA) for assignments, quizzes, and examinations. The fraction of students performing well enough to achieve a grade of 2.5 or higher is our measure of success. The use of technology has permitted a reallocation of instructors' and teaching assistants' time, shifting it from repetitive jobs such as grading and record-keeping to tasks more directly related to student achievement. The prompt and accurate feedback which this technology provides can be used in large lecture courses in several ways to improve student success rates. Having information on students' performance and difficulties at an instructor's fingertips also provides an opportunity for problems to be addressed in a timely manner.

Background

In Spring 1993, the networked software system CAPA was first implemented in a physics course [1,2]. It is a tool to write and distribute personalized assignments, quizzes, and examinations. Students use the system either via VT100 terminal emulation or through the World-Wide-Web. CAPA focuses on achievement rather than on the speed or correctness of an initial response, thereby eliminating continual judging and ranking during the learning process. There was a significant increase in the time-on-task by students and at the same time a remarkably high level of student acceptance [2].

In Fall 1995 an Asynchronous Learning Network was implemented and used in combination with CAPA. The course was organized without recitation sections, thus reducing staffing requirements. The total staff for the course was two-third that of previous years and was sufficient for the ALN and the Physics Learning Center where students could obtain on-line and face-to-face help respectively. The ALN was implemented using 'FirstClass' software [3]. In addition to stimulating students to interact via the network, the ALN provides an instructor with a tool that multiplies his effectiveness. Discussions of various topics or answers to questions can reach all students at any time outside class hours. In this initial use of CAPA and ALN, the emphasis was on establishing a higher standard for the course and more efficient teaching.

Through the use of this technology, we hope to overcome some of the factors that can contribute to students not achieving their goals. These factors include: deficient preparation and a lack of awareness thereof; misconceptions, especially in physics; insufficient mathematical problem-solving skills; excessively demanding and difficult course schedules; and the students' perception of the quality of education [4].[2]

Project Description

The key elements of the project are (a) to implement an Active-Learning Environment both in the lecture and in student assistance provided via ALN and personal mentoring sessions, (b) to identify students at risk early and implement a program to mentor those students, and (c) to assess the impact various components have had on success rates.

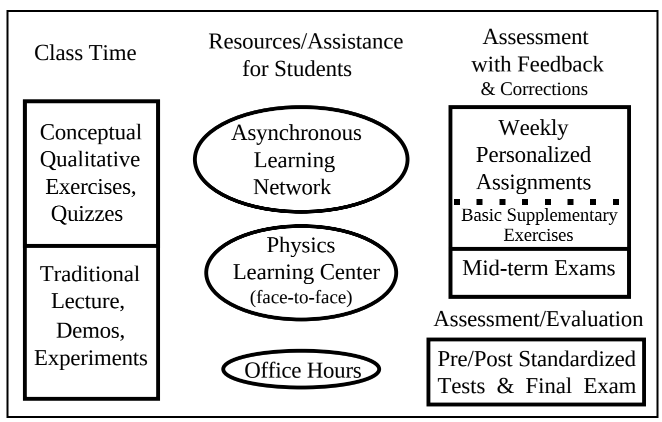


Figure 1: Components of the Active Learning Environment in the large physics course.

[1] Supported by the Alfred P. Sloan Foundation.

[2] Other factors include the feeling that they are falling behind, excessive work to pay tuition and bills, and emotional and physical well-being [4].

Figure 1 illustrates approximately the distribution of time within each of the categories. Nearly half of the time in lecture is devoted to students being actively involved in tasks related to understanding of basic principles and in discussing these ideas with neighboring students [5-7]. Recitation sections are eliminated. The ALN and the physics learning center become the major methods of providing student assistance. The goal is to improve conceptual understanding both by demonstrations designed to contradict misconceptions and questions that stimulate discussions among students and with instructors, both on the ALN and in person.

A well established problem in introductory physics courses is the tendency of students to reach for a formula and then ‘plug and chug’ to get an answer [8]. To address that problem and lead students away from this plug in the formula approach, about a third of every exam, including the final exam dealt with concepts and required no numerical calculations. The importance of conceptual understanding is illustrated in Figure 2, which shows the relationship between student performance on conceptual and story-type numerical problems on the final examination in Fall 1996. The correlation between scores on conceptual and numerical questions is easily seen. The correlation index r = .592 indicates a strong tendency for students who performed well on one type of question to also perform well on the other type of question.

CAPA is well suited for conceptual questions because of the tools and templates available which facilitate coding of problems. It is in the conceptual area that *CAPA* differs most significantly from other computerized assignment systems [9-14]. Two examples of conceptual problems used in assignments in Fall ’96 are shown in Figures 4 and 5. Such questions generate considerable discussion among students. When two students help each other, they both learn from the experience. Students must then combine their conceptual understanding with their mathematical skills to solve the "story-type" problems.

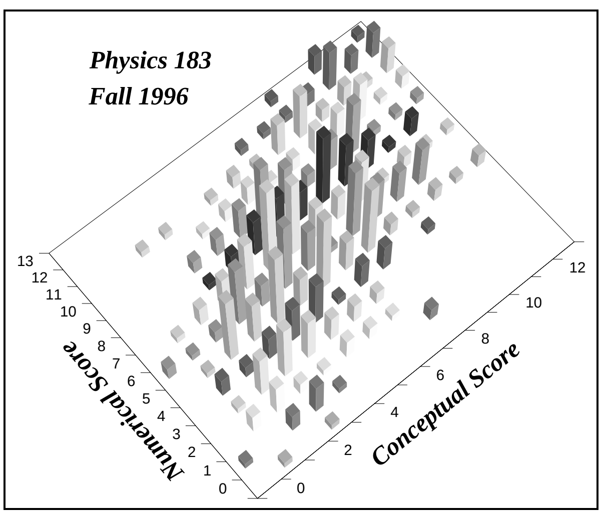


Figure 2: Frequency distributions of scores on conceptual questions and story-type numerical problems on the final examination in Fall 1996.

Many of the problems and questions in assignments, quizzes and in classroom exercises emphasize concepts. Figure 3 shows a sample lecture exercise used Fall ’96. In that exercise, only statements 1, 2, and 5 were initially selected by a majority of the students in the class as possible actions even though all are possible. Once these actions are discussed and demonstrated, they become ‘obvious’.

A) Select all possible actions:
Frictional Forces can
1) Slow a body down
2) Increase the temperature of a body
3) Accelerate a body
4) Maintain a body’s velocity constant
5) Keep a body stationary
6) Make a body move in circle
7) Lift a body

B) For each statement which you have selected, make a diagram (or describe) a practical situation for which a frictional force gives the indicated result.

Figure 3: Example of a conceptual exercise during the lecture.

Figure 4 shows versions of the same conceptual problem for two students. The number of possible versions of the problem is very large because of the permutations of the labels in the figure. The statements appear in random order, and each presents several ways of addressing a particular concept. Thus students collaborating on such problems must actively do so by studying each other’s diagrams in detail, resulting in mutually beneficial learning interactions.

A second problem is shown in Figure 5. It deals with accelerated motion and involves Newton’s well known second law. The statements focus on the concept of Net Force on a body and on the very meaning of a body, which as the hint explains, can be a set of objects connected by internal forces [15].

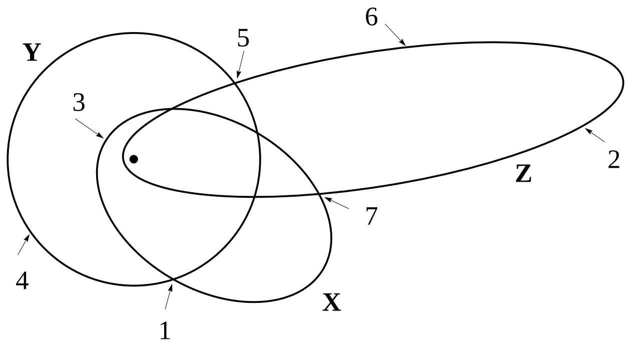
The answer keys for the examples in Figures 4 and 5 are given at end of the bibliography.

Assessment

Fall ’96 was the the first of the four semesters of the project. The components of the plan fully implemented were the ALN, the assignments, quizzes, examinations, supplementary exercises, numerous in-lecture exercises and a pre-test and post-test, the “Force Concept Inventory" to measure the students understanding of force and motion [16]. Identifying and mentoring students at risk, especially early in the semester, was not done on a large enough scale to assess impact, as software to do so efficiently was not yet ready.

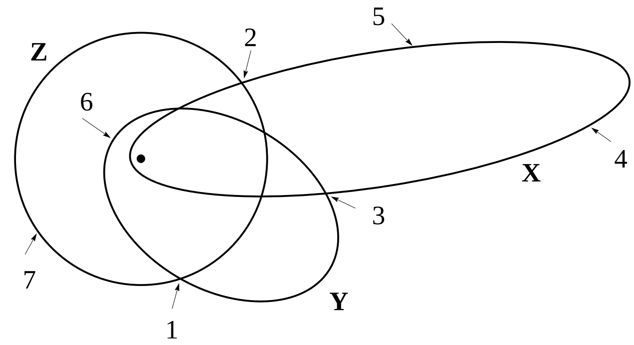
Table 1 shows the ordinary correlations and the partial correlations controlling for pre-test score between Final exam and performance in various components of the course [17]. All correlations in Table 1 are statistically significant with p less than .001. The ordinary correlations indicate that students who scored higher on various aspects of the course tended to score higher on the final exam.

1. [2pt] Asteroids **X**, **Y**, **Z** have equal mass (9.0 kg each). They orbit around a planet with M = 4.0 x 10^{24} kg. The orbits are in the plane of the paper and are drawn to scale.



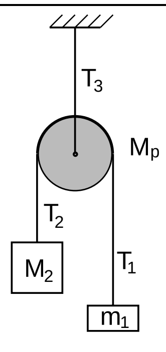
Select G-Greater than, L-Less than, or E-Equal to.
A) The angular momentum of **X** at 7 is .... that at 1.
B) At 5, **Y**'s angular velocity is .... that at 1.
C) The period of **X** is .... that of **Z**.
D) The angular velocity of **X** at 3 is .... that at 7.
E) **X**'s angular momentum is .... that of **Y**.
F) The period of **Y** is .... that of **X**.
G) At 1, **Y**'s angular velocity is .... that of **X**.

1. [2pt] Asteroids **X**, **Y**, **Z** have equal mass (5.0 kg each). They orbit around a planet with M = 3.0 x 10^{24} kg. The orbits are in the plane of the paper and are drawn to scale.



Select G-Greater than, L-Less than, or E-Equal to.
A) The period of **Y** is .... that of **X**.
B) At 1, **Z**'s angular velocity is .... that of **Y**.
C) **Z**'s angular momentum is .... that of **Y**.
D) The period of **Y** is .... that of **Z**.
E) At 2, **Z**'s angular velocity is .... that at 1.
F) The angular momentum of **Y** at 6 is .... that at 1.
G) The angular velocity of **Y** at 3 is .... that at 6.

Figure 4: Example of two versions of the same problem for two different students.



2. [2pt] A pulley with mass M_p and a radius R_p is attached to the ceiling, in a gravity field of magnitude g=9.81 m/s^2 and rotates with no friction about its pivot. Mass M_2 is larger than mass m_1. T_1, T_2 and T_3 are magnitudes of the tensions; CM means center of mass. (Select T-True, F-False, G-Greater than, L-Less than, E-Equal to. If the first is T, the second L and the rest E, enter TLEEEE).
A) The CM of m_1+M_2+M_p does not accelerate.
B) m_1g is ..... T_1
C) The acceleration (magnitude) of M_2 is ..... that of m_1
D) T_2 is ..... T_1
E) $T_1 + T_2$ is ..... T_3
F) T_3 is ..... $m_1g+M_2g+M_pg$

Figure 5: Problem testing conceptual understanding of Newton's Second Law, **F** *= m***a***.*

Table 1: Ordinary and partial correlations.

Item	Ordinary r	Partial r
Homework %	.300	.281
Quiz %	.639	.591
Supp. Ex. %	.460	.487
Midterms %	.795	.745
# days absent	-.352	-.349
Pre-test score	.361	n/a
Post-test score	.551	.381

Notably, those who were absent more often tended to perform worse on the final. These findings are not unexpected [4,18]. One would expect students who are brighter or who have more experience in science and physics to be more successful (and perhaps to attend class more regularly). The partial correlations address this aspect of the data by examining the relationship between final exam scores and the other variables after controlling for differences on the pretest. That is, the partial correlation between homework and final exam scores indicates that there is a strong positive relationship between success on homework and success on the final, after accounting for differences on the pretest.

Although the use of computer entry for solutions to assignments was optional, essentially all students elected to do so for the obvious advantage of correcting errors. Only 3% of papers were turned in for hand grading for the first assignment, 1% for the second, and none thereafter. Three evenings each week during the semester, seniors physics students provided assistance on-line via the ALN. All students in the course were given an account on the ALN. About half (52%) of the students used the ALN. Thus students electing to use the ALN represent self selection in the use of that technology, and performance differences shown below may simply reflect a higher level of motivation for that group. As shown in Table 2, there is a marked difference in performance for these students.

Table 2: Performance of students using the ALN.

Final exam	+10%
Assignments	+5%
Quizzes	+11%
Days absent	-12%

By using the class ALN, students are actively seeking to learn. We are currently unable to judge the impact of the personal help sessions as no record of student interactions were kept, a deficiency we plan to correct next Fall.

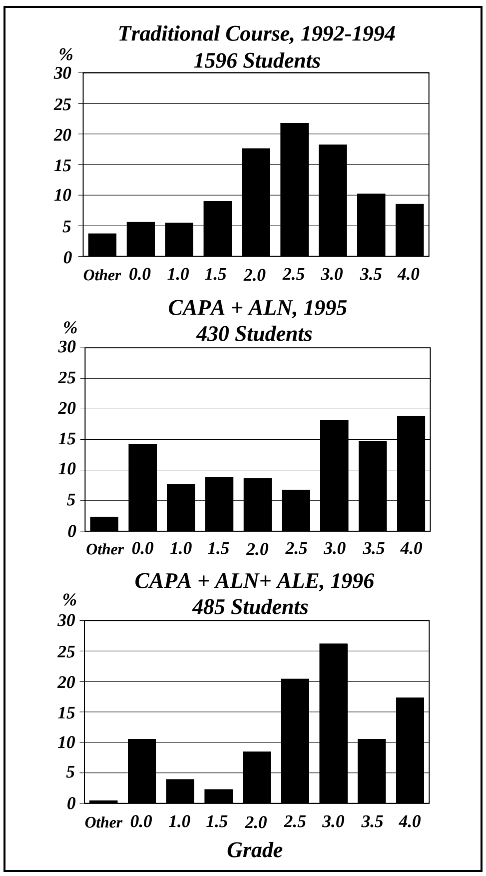


Figure 6: Distribution of grades in Physics 183 for the past five Fall semesters. The first graph is for Fall '92,'93 and '94, where the course was taught in the traditional format. The second is for Fall '95, with the initial implementation of both an ALN and the use CAPA. The third is for Fall '96, the first semester of the current project.

The grade distributions in Figure 6 do not include the large number of students who dropped the class. The first graph corresponds to the traditional-style course consisting of two lecture sections with two professors lecturing and several other professors in the role of teaching assistants, leading a large number of recitation sessions of approximately 30 students. That distribution has the classical bell shaped curve.

Fall 1995 represented our initial use of an ALN and of CAPA in this calculus based physics course. The grade distribution that semester, with the ALN-CAPA course shows a marked change in grade distribution. In spite of a higher standard established for the course, a larger fraction of students achieved grades of 3.5 or 4.0 than in previous years. The change in distribution appears to be the result of the increased time-on-task, of the instant feedback provided [19-21], and of the opportunity to correct errors. In order to learn, students need to know what they don't know!

There was no significant change in the fraction of students achieving a score of 2.5, but that score represented a higher achievement level because of the more rigorous course standard.

This result is consistent with results in another physics class with similar use of technology: for equivalent levels of difficulty mid-term and final exam scores improved substanstially as shown in Figure 7 [22].

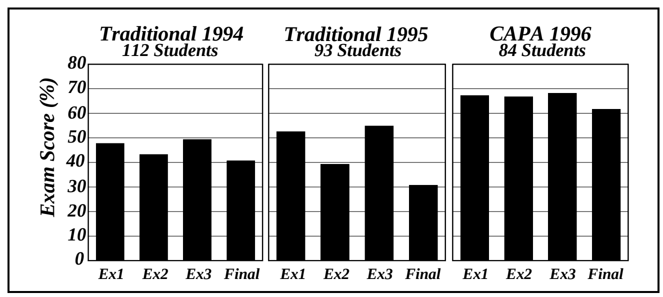


Figure 7: Average examination scores for the introductory physics class LBS262 for three consecutive years taught by the same instructor. CAPA was introduced in 1996.

The third graph in Figure 6 represents Fall '96 grades on the basis of the same numerical scores as in the Fall '95. Increased experience with the ALN and discussions with colleagues at other institutions enabled a better implemention than in the previous year. All the elements of the learning environment shown in Figure 1 were implemented, including lecture exercises and supplementary assignments not done in the previous Fall. In order to minimize bias on measured student performance outcome, a faculty member not involved in the project was responsible for the examinations to maintain the same level of difficulty. That faculty member[3] wrote or selected the examination questions used. His main responsibility was to assist students in the Physics Learning Center. A significant improvement in student performance can be seen from the third graph in Figure 6. It should not be surprising that such technology has a positive impact [9-14]. It implements effectively and efficiently well established components of learning: Feedback is given immediately, students correct

[3] Prof. N. Birge

their work, and they are given the opportunity to seek and obtain assistance in highly flexible ways.

An unexpected result was a remarkable decrease in the number of student who dropped the class. In 1995, the enrollment dropped from 475 to 430 students, a decrease of 45 students. In Fall 1996, it was initially 496 and ended at 485, a decrease of only 11 students in enrollment.

These early results are indeed encouraging, but we will be in a much better position to evaluate the outcome after the next three semesters of the project have been completed. The assessment and evaluation of the project at that time may also be less affected by the 'Hawthorne Effect' or some 'Happy Coefficient' associated with trying new things [23].

Conclusions

Results are encouraging as the program appears to be meeting its goals. Technology is helping to provide students with the opportunity to excel which can be a highly motivating factor [24]. In an active learning environment, technology has helped to implement several well demonstrated components of effective education: immediate feedback, correction of mistakes, and help in learning difficult material. Implementation of the program of early identification and mentoring of motivated students at risk, together with assessment and evaluation following the current semester will help guide next year's implementation.

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Key to Multiple Choice problems:

Fig. 4 Version 1: EELGLEG Version 2: LGGEEEL

Fig. 5: FLEGLL