Using Networked Tools to Promote Student Success 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. Networked systems have been employed to generate personalized assignments and to provide instant feedback and on-line assistance to students. Traditional recitation sections have been eliminated and their role filled by networked assistance and by a centralized learning center where the Socratic method was used to promote understanding. Participatory exercises and quizzes during lecture sessions were used to foster a more active learning environment. This approach which incorporates a considerable use of asynchronous learning network technology can significantly improve student achievement in large classes.

I. INTRODUCTION

A project was initiated in the Fall of 1996 to assess the degree to which use of technological tools could help to enhance student success in a 500-student calculus-based physics course for engineers. Two software tools constituted our Asynchronous Learning Network (ALN). One was a networked system to implement a computer-assisted personalized approach (CAPA) for assignments, quizzes, and examinations. The second, was a conferencing and bulletin-board system which allowed students to post and answer questions and to interact with each other and with the instructional staff. The fraction of students performing well enough to achieve a grade of 2.5 and higher was our measure of success with 4.0 as the highest possible grade. The use of technology has permitted a reallocation of instructors' and teaching assistants' time, shifting it from repetitive jobs such as grading and keeping records to tasks more directly related to student achievement. The prompt and accurate feedback students receive should help promote learning and understanding. Information on students' performance is readily available to instructors who can then address problem areas in a timely manner.

II. BACKGROUND

In Spring 1993, the networked software system CAPA was first implemented in a physics course[1,2] . It is a tool for instructors to write and distribute printed personalized assignments, quizzes, and examinations, and has extensive course management and analysis features. Students use the system either via VT100 terminal emulation or through the World-Wide-Web. CAPA focuses on 'end result' 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 a conferencing system was implemented using FirstClass™ software[3] 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-thirds that of previous years. This smaller staff was sufficient for the ALN and for the Physics Learning Center where students could obtain on-line and face-to-face help respectively. In addition to stimulating students to interact via the network, the ALN provides instructors with a tool that multiplies their effectiveness. Discussions of various topics or answers to questions can reach all students at any time outside class hours. In this initial use of an ALN, the emphasis was on establishing a higher standard of achievement for a given grade in the course.

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

Through the use of technology, we hoped to overcome some of the factors that 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]. Among other factors are the feeling that they are falling behind, excessive work to pay tuition and bills, and emotional and physical well being[4].

III. Project Description

The key elements of the project were (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.

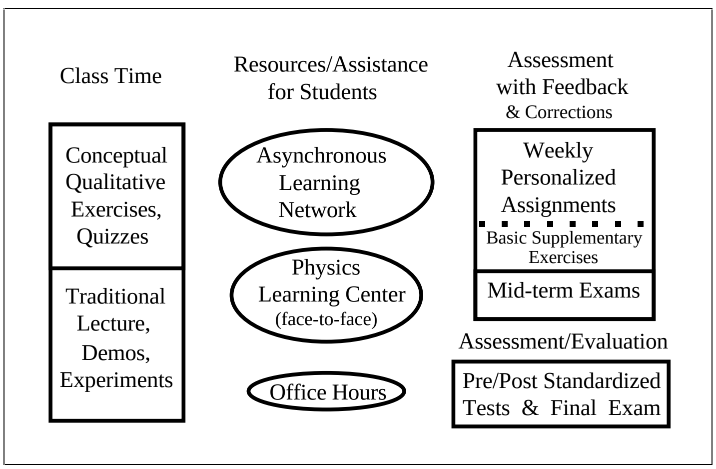
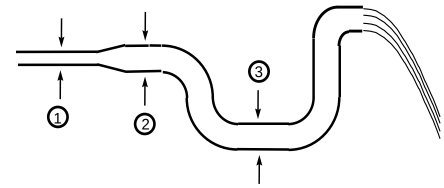


Figure 1: Components of the active learning environment in the large physics course.

Figure 1 illustrates the various components of the class. Nearly half of the time in lecture was devoted to students being actively involved in tasks related to understanding of basic principles and in discussing these ideas with neighboring students[5,6,7]. The goal was 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. Recitation sections were eliminated. The ALN and the physics learning center became the major methods of providing student assistance. In the learning center, the Socratic method was used by the teaching staff when interacting with students.

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 one third of every exam, including the final exam, dealt with concepts and required no numerical calculations. Figure 2 is an example of such a question. It deals with Bernoulli's principle for the flow of an ideal fluid in a uniform gravitational field.

2. [3pt] The side view of a pipe is shown. The pipe diameter increases and then remains constant. P_i is the pressure, and v_i is the speed of a non-viscous incompressible fluid, at locations i = 1, 2, 3.



Select G-Greater than, L-Less than, or E-Equal to. (If the first is G and the rest are L, mark GLL)
A) v_2 is …. v_1. B) P_2 is …. P_3 C) P_1 is …. P_2

Figure 2: Conceptual question from an examination.

The importance of conceptual understanding is illustrated in Figure 3, 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.

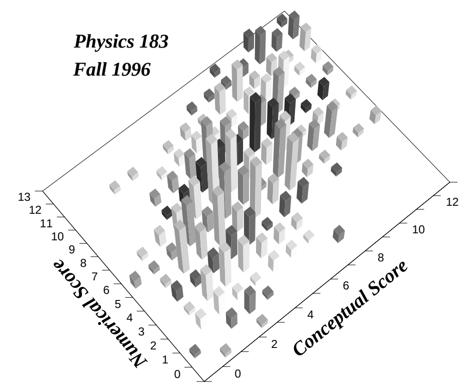


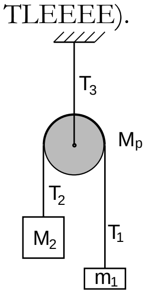
Figure 3: Frequency distributions of scores on conceptual questions and story-type numerical problems on the final examination in Fall 1996.

The correlation index r = .592 indicates a significant 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 to facilitate coding of these problems. It is in this area that CAPA differs most significantly from other assignment systems[9,10,11,12,13,14,15]. Examples of conceptual problems which were used in assignments in Fall '96 are shown in Figures 4 and 5.

The problem shown in Figure 4 deals with accelerated motion and involves Newton's second law. The statements focus on the concept of net force (and net torque) 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[16].

4. [2pt] A pulley with mass Mp and a radius Rp is attached to the ceiling, in a uniform gravity field g, 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. (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 center of mass of m_1+M_2+Mp does not accelerate.
B) m_1g is ..... T_1
C) The magnitude of the acceleration 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+Mpg

Figure 4: Problem testing conceptual understanding of Newton's Second Law.

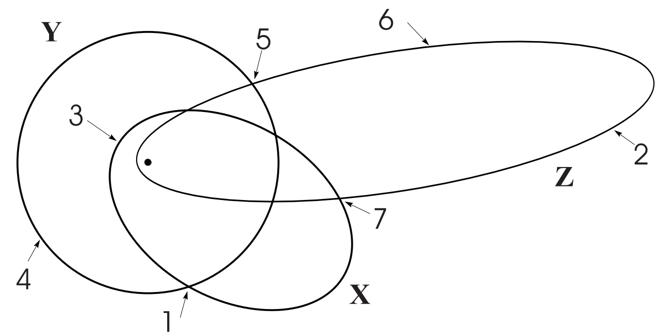
The hint available to students when they get the problem wrong is:

HINT: `This problem deals with Newton's second law for linear and for rotational motion. Think about acceleration and the net force on 'a body'. A 'body' can be a set of objects connected by internal forces. Don't forget that the pulley has mass and therefore a moment of inertia.`

In addition to the hint, students using a browser can view a simulation of the motion to help them understand that the center of mass of m_1, M_2 and the pulley accelerates

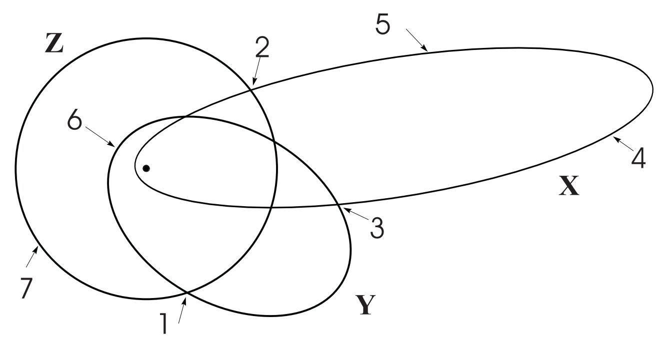
Figure 5 shows versions of the same conceptual problem for two students.

5. [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**.

5. [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 5: Two versions of the same problem for different 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 may present 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. 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. The answer keys for the examples in Figures 2, 4 and 5 are given at end of the bibliography.

Problems and questions in quizzes and in classroom exercises also emphasized concepts. Figure 6 shows a sample lecture exercise used during Fall 1996.

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 6: Example of a conceptual exercise during the lecture.

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'.

IV. ASSESSMENT

Fall 1996 was the first of the four semesters of the project. The components of the plan fully implemented were the conferencing and bulletin board system, personalized 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[17]. Identifying students at risk, especially early in the semester, and advising them was not done on a large enough scale to assess impact, as software to do so efficiently was not yet ready. This, however, was done in Fall 1997.

Table 1 shows the ordinary correlations and the partial correlations controlling for pre-test score between the final exam and performance in various components of the course during Fall 1996.

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

All the 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. Notably, those who were absent more often tended to perform worse on the final. Attendance was obtained from the un-announced quizzes given during lecture. The findings in table 1 are not unexpected[4,18]. One can expect students who are brighter or who have more experience in science and physics to succeed more easily (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, senior physics students provided assistance on-line via the network. All students in the course were given an account on the FirstClass™ conferencing system. About half (52%) of the students used that system for assistance. Thus students electing to use the system 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 conferencing and bulletin-board system.

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

[*] A partial correlation is a correlation between two variables after removing from them the linear relations of another variable, in this case, performance on the pretest.

By using the conferencing system, students were actively seeking to learn. We also have some evidence of the positive impact of the personal help available to students in the physics learning center. Analysis based on student responses in Fall 1997 indicates that it was used more by students whose scholastic record was below the average for the class, yet their performance on the final was very near the class average.

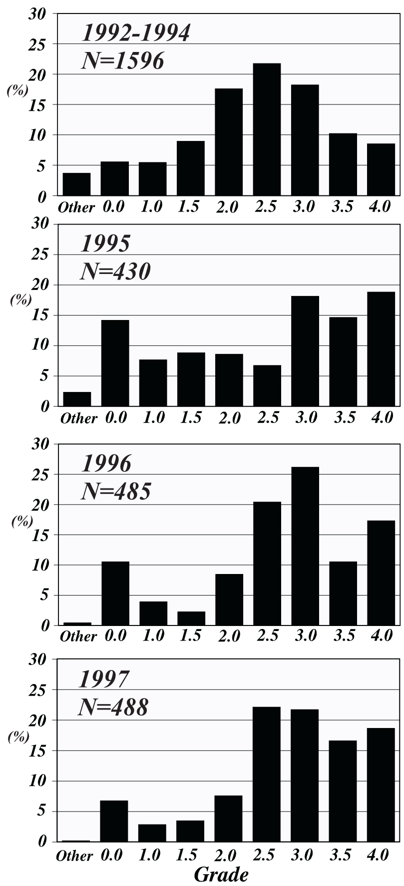


Figure 7: Distribution of grades in Physics 183 for the past six Fall semesters. The first graph is for Fall 1992, 1993 and 1994, where the course was taught in the traditional format. The second is for Fall 1995, with the initial implementation of an ALN. The third is for Fall 1996 and the fourth for Fall 1997.

The grade distributions in Figure 7 include all the students still on the class list at the end of the semester. 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. Of the 1596 students represented, 59% achieved a grade of 2.5 or above.

Fall 1995 represented our initial use of ALN technology in this calculus based physics course Our implementation of the FirstClass™ conferencing system left much to be desired and use by students was quite small. The grade distribution that semester shows a marked change from the bell shape of previous years. A higher standard was set for the course relative to previous years by increasing the number of problems requiring the use of calculus and by increasing the number of problems whose solutions required understanding two or more concepts in assignments and examinations. In spite of this higher standard, 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[19,20,21], and of the opportunity to correct errors. In order to learn, students need to know what they don't know!

About the same percentage (58%) of the students in Fall 1995 achieved a grade of 2.5 or higher. This was similar to previous years, but due to the more rigorous course standard that grade represented a higher achievement level.

The third graph in Figure 7 represents Fall 1996 grades on the basis of the same numerical scores as in the Fall '95. Increased experience with the various tools and discussions with colleagues at other institutions enabled a better implementation than in the previous year. All the elements of the learning environment shown in Figure 1 were implemented, including lecture exercises and supplementary assignments. In order to minimize bias on measured student performance outcome, a faculty member who was not a member of the project team was responsible for the examinations to maintain the same level of difficulty. That faculty member, Prof. N. Birge of the department of Physics and Astronomy, wrote or selected the examination questions used. A significant improvement in student performance can be seen from the third graph in Figure 7. 74% of the students achieved a grade of 2.5 or higher. It should not be surprising that such technology has a positive impact[9,11,12,14]. It implements effectively and efficiently well established components of learning: feedback is given immediately, students correct their work, and they are given the opportunity to seek and obtain assistance in highly flexible ways.

In Fall 1997 a different conferencing system, Alta-Vista™ Forum[23], which operates from a standard browser was used. The statistical correlations and conclusions presented in Table 1 are well reproduced. The 1997 grade distribution, shown in the bottom graph of Figure 7, is consistent with that of 1996 and shows a similarly high success rate, i.e., 78% vs 74% of students achieving a grade of 2.5 or higher.

The improved student performance we have observed is consistent with results in another physics class with similar use of technology where for equivalent levels of difficulty mid-term and final exam scores improved substantially as shown in Figure 8.[22]

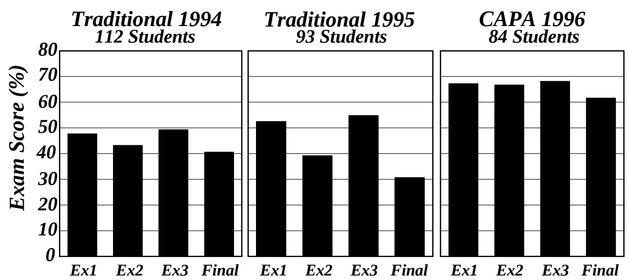


Figure 8: Average examination scores for the introductory physics class, LBS262, for three consecutive years taught by the same instructor. CAPA was introduced in 1996.

An unexpected result was the decrease in the 'drop out' rate which we define here as students who took the first hour exam early in the semester but did not take the final exam (Not taking the final results in a 0.0 grade.) In 1995, 30 out of 447 students 'dropped out', which represents 6.7% of the students in the class; in 1996, the number was 22 out of 492 (4.5%) and in 1997, the number was 16 out of 493 (3.2%).

These results are indeed encouraging, and are similar to the positive results found recently in an electrical engineering course using similar technique, i.e., computer dialog combined with rapid feedback from an on-line grading system[14]. We are now in a good position to tune and refine out techniques including improving the program of early identification and interaction with motivated students at risk. The assessment and evaluation of the project so far does not appear to be strongly affected by the 'Hawthorne Effect' or some 'Happy Coefficient' associated with trying new things.[24]

V. CONCLUSIONS

The increase in students succeeding (~18%) indicates that the project is having a significant impact. Technology is helping to provide students with the opportunity to excel which can be a highly motivating factor.[25] 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. Improvements in the technological tools are underway to reduce the time and effort required to prepare course materials and administer large classes and should thus facilitate and encourage their adoptions.

ACKNOWLEDGEMENTS

The Alfred P. Sloan Foundation support of this project is gratefully acknowledged. We are indebted to Professor D.A. Kashy of Texas A and M University for the statistical analysis of the impact data, and for valuable discussion as to the interpretation of the results.

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Solution key to conceptual problems:
Figure 2: LLL
Figure 4: FLEGLL
Figure 5, Top Version: EELGLEG
Figure 5, Bottom Version: LGGEEEL

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