ALN TECHNOLOGY ON CAMPUS: SUCCESSES AND PROBLEMS

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Introduction

This paper briefly summarizes the principal results obtained with the use of CAPA (Computer Assisted Personalized Approach) as an Asynchronous Learning Network (ALN) tool and presents recent data concerning student performance using this tool. CAPA is a network tool designed to facilitate and improve the way assignments, quizzes, and examinations are provided and graded in large enrollment courses and was first implemented for a 90-student class in 1992 [1]. The system provides immediate feedback to students (and instructors) on conceptual understanding and correctness of solutions, and it also includes a variety of statistical and course management features [2]. The very positive initial student response and the interest of instructors in other fields provided the impetus to continue to develop and expand the systems capabilities, and it is currently licensed at over 50 institutions. It is also being used for science and mathematics courses in two area high schools, East Lansing and Grand Ledge.

Background

To assess the educational impact of ALN, both subjective and objective measures have been used. They include (1) surveys of students (2) instructors comments, and (3) examination performance and course grade distributions.

Surveys of students indicate that students' attitudes have been and continue to be highly positive, and students give the system high grades for helping them learn and understand [1,3-6]. Instructors also have expressed satisfaction and often enthusiasm [7]. Investigation of exam performance and grade distributions has demanded some control on the performance standards used and grading methods employed. Briefly, an independent instructor evaluated the difficulty of examinations, and grades are based on an absolute grading scale [8]. With fixed scale assignment of grades, exam performance and grade distributions represent similar measures, which we discuss below in some detail. We note that a superordinate difficulty in assessing educational impact is the dearth of widely used standards that provide a more reliable and objective scale on which to measure student achievement, and technology may be just the tool needed to create such standards.

Previous analyses of data generated by on-campus physics courses using the CAPA system have resulted in a number of findings, many of which also have been replicated in other disciplines and at other institutions [3,5,9-11]:

- A majority of students, typically 80%, respond that CAPA helps them learn and understand the course material.
- The technology allows high standards to be implemented while providing students with the opportunity to achieve those standards.
- The time students spend working on assignments and other course requirements has increased by nearly a factor of 2 and approaches the recommended 2 hours outside of class per lecture hour.
- Frequent assignments with firm electronic deadlines keep the course on schedule and help to inhibit the tendency of some students to procrastinate and fall behind.
- Allowing multiple tries on assigned problems with no penalty is highly motivating; most students strive to get all the work done correctly.
- There is a high level of interaction among students and between students and staff. A smaller teaching staff can do more for (and with) students. Reassigned staff can provide a greater level of Socratic interaction with individual students.
- Scores on examinations show a substantial increase, even with higher standards and harder problems.

- Controlling for standards, a larger proportion of students succeed and an even greater proportion excel in the course, with female students benefiting even more than males.
- With the computer doing the grading, the instructor is viewed by students to be more a mentor rather than a judge.
- Developing and testing materials well adapted to the technology, especially material that is designed to improve conceptual understanding, is costly in both time and effort.
- Interactions and collegiality has greatly increased among faculty sharing their experience.
- Faculty satisfaction is high in spite of the increase in the level of effort required.

CAPA features

The CAPA system consists of several applications. For the student, answers to assigned problems are checked and the student is given feedback on correctness, as well as specific information on a wide variety of errors that are likely to occur: units, significant digits, and various formatting errors that prevent a proper interpretation of the student's answer. It also includes a discussion forum that is readily accessible where students can interact with one another as well as with the teaching staff.

For the instructor, it provides a broad set of pre-coded templates and examples that facilitate the coding of a variety of problems. These include:

- Numerical problems where each student gets randomly assigned values for the variables
- Select all the correct statements from a list of statements
- Assign a conclusion to each statement of a list
- Identify features in a diagram, with both the labels and the list of features randomized
- Problems that require a graphical solution
- Rank items based on quantitative or qualitative measure
- Problems with an answer consisting of several parts (and)
- Problems with more than one correct answer (or)
- Subjective essays, read and evaluated by instructor with key-words highlighted by the computer
- Problems with expressions as answers where students enter symbolic formulas
- Individualized applets as basis of interactive questions
- Sound and speech as the medium for the questions

New Results

We report here some new results for Fall 1999 and compare them with those of previous years. The current project, initiated in 1995, implemented an on-campus ALN in a 500-student introductory course, Physics for Scientists and Engineers (Phyl83). Technology was used in essentially all aspects of the course, including mid-term examinations that combine both formative and summative assessment [12,13]. Lecture time was made more active with participatory exercises included during half the class meetings. Numerous unannounced individualized quizzes were given throughout the semester and resulted in 90% average attendance, a remarkably high value. In addition to examinations and quizzes, individualized homework assignments were given, and students were able to enter their responses online and obtain immediate feedback concerning the correctness of their responses. When homework assignments were answered incorrectly, students were allowed to reevaluate their answers and try again. Commercial software was initially used to implement a networked discussion forum, but recently a web-based discussion forum has been integrated in the CAPA system.

One question we studied is the relation of conceptual understanding to success in story-type problem solving skill. Forty percent of examination questions were conceptual, reflecting the importance of understanding of scientific concepts. Students worked on similar questions as part of their assignments. The questions were designed to help students appreciate the concepts underlying quantitative numerical solutions.

Some questions can lead student to resolve misconceptions on their own by confronting them with contradictions, while others illustrate concepts from a variety of situations [14-18]. The overall correlation coefficient between performance on conceptual problems and computational problems, summing over all problems on the midterms and final exam, was r = .703, p < .001. This strong correlation between conceptual understanding and problem solving confirms that the initial emphasis on implementing a broad variety of conceptual problems formats was a good design choice. Several of these features are found in other similar systems [19-25].

As noted above, there have been several indications that the ALN allows a greater number of students to achieve the goals of the course and simultaneously provides an environment in which a greater proportion of students can excel. Figure 1 compares the 1999 grade distribution to previous years by showing the evolution of the distribution of grades starting in 1992 and illustrates the large change associated with the implementation of ALN technology. The 1992-1994 histogram represents the grade distribution when the course was taught in the traditional manner. 1995 was a transition year (not shown) when the first ALN was implemented. The proportion of students meeting the goals that year was essentially unchanged from 1992-1994, reflecting in part higher standards and our lack of experience in ALN use [8].

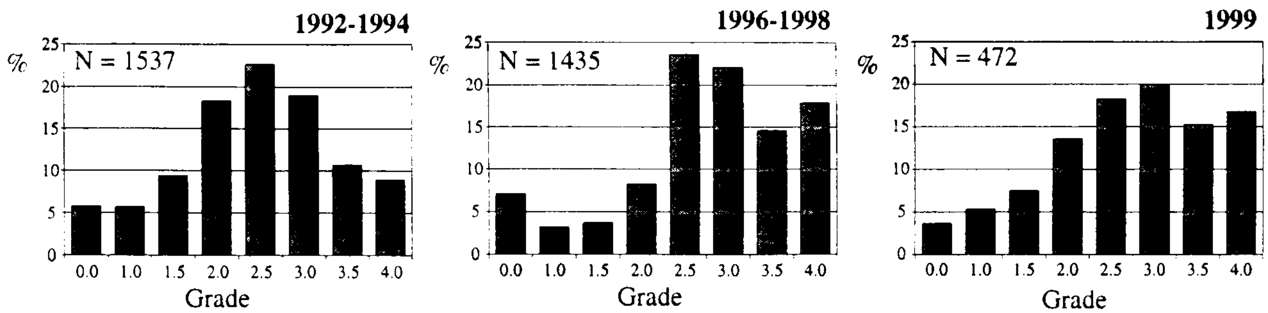
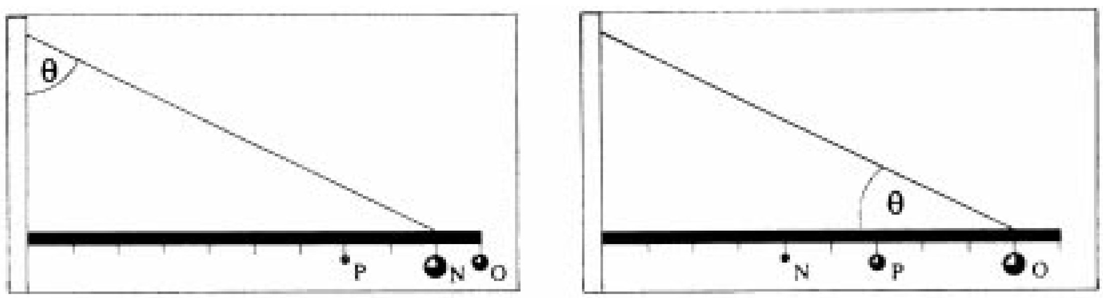


Figure 1: Distribution of grades in Phy183

There is a clear shift away from the traditional bell-shape in the l996-l998 years with ALN. The proportion of students excelling, (grade 3.5 and 4.0), 32%, is much higher than in the traditional lecture and remains at that level in 1999. It appears that motivated students work hard and take advantage of learning opportunities that instructors can provide, using technology to overcome deficiencies in incoming preparation [4].

In l996-l998, 78% of the Phyl83 students achieved the goals, i.e., had grades of 2.5 or above. This represents an 18% increase, so that typically 90 more students achieve that level. In 1999, 70% of the students achieved the goals. This represents a decrease from the 78% average in the previous 3 years. The decrease may be due to a somewhat more difficult final exam or perhaps it is only a random fluctuation, but we believe that it may represent a real decrease in student achievement. An enterprising student developed an elaborate web discussion forum where students could get answers and formulas, often with little understanding, thus defeating the goals in the design of most individualized numerical and conceptual problems. A recent analysis shows that students' use of that web site is negatively correlated with examination performance, (r = -.348, p < .001); i.e., students using it more tended to score lower on midterm exams, quizzes, and the final. Thus technology is being used to promote "plug and chug", finding a formula to plug in variables and grinding out the answer, which is quite the opposite of learning and understanding [26]. In contrast, the correlation for students using the discussion site provided with the course was positive [27].

To respond to this new challenge, we have been working to develop new problem formats that make copying without understanding much more difficult, while not increasing the actual complexity of these problems. The formats include individualizing the labeling of figures in numerical problems, providing data in histogram or graphical form, and applets where the students' actions are transmitted to CAPA for analysis. Versions of such a problem for two different students are shown in Figure 2. Values and labels can differ as well as the positions on the diagram, in this case, the position of the masses and the identification of the angle. Communications among students on either web site is likely to be instructive, as no single plug-in formula solves this relatively straightforward problem. In the future we will need to measure the impact of this approach.



2. [2pt] A 4.30 kg beam has a length 1.30 m and is suspended in a horizontal position as shown. There are 10 equally spaced attachment points, 13.0 cm apart with three masses hanging from the beam. A thin cable attached 13.0 cm from the end makes an angle of 53.0^{o} with the wall as shown. The masses are N = 8.00 kg, 0 = 6.00 kg, P = 3.00 kg. Calculate the tension in the cable.

2. [2pt] A 3.90 kg beam has a length 1.20 m and is suspended in a horizontal position as shown. There are 10 equally spaced attachment points, 12.0 cm apart with three masses hanging from the beam. A thin cable attached 12.0 cm from the end makes an angle of 35.0^{o} with the wall as shown. The masses are N = 4.00 kg, 0 = 8.00 kg, P = 5.00 kg. Calculate the tension in the cable.

Figure 2: Two versions of the same problem.

Are the improvements we have seen the same for male and female students? A unique opportunity to examine this question is provided by an earlier physics course in which the first semester of a course, Phy231, was taught using traditional methods and the second semester of the sequence was taught using CAPA. A total of 267 students participated in both parts (N = 267). Figure 3 shows the grade distributions for male and female students, and one can see a shift indicating that female students' grades tended to show greater improvement during the second semester (using CAPA) relative to male students' grades. To better judge these data, we compared the average grade change for this sequence with one in which both semesters were taught using traditional methods (N = 428). With CAPA, the average grade changes of women was greater than that of men by 0.16 (on a 4.0 scale [28]. A similar observation was made in a microeconomics course. Male students' grades in the transition from traditional to computer enhanced rose from 2.63 to 2.73 while those of female students rose from 2.36 to 2.72, with a preliminary analysis pointing to higher homework grades as the reason [29].

To see whether evidence for this effect could be found in the 1999 Phy 183 class for engineers, we looked at the exam performance by gender and over time. A two-way mixed model ANOVA (Analysis of Variance) was conducted with sex as a between-subjects factor and time (exam1, exam2, exam3, final) as a within-subjects factor. The ANOVA yielded a significant main effect of gender indicating that men, on average, scored higher than women. The analysis also indicated a significant interaction between gender and time. To examine the interaction, independent groups t-tests were conducted comparing men and women's performance at each time point. Figure 4 shows the women's average score relative to that of men. At exam 1, four weeks into the semester, men had a score on the average 18% higher than women, a statistically significant difference. At exam 2, seven weeks into the semester, men again outperformed women, but their score was only 6% higher, a marginally significant difference. At exam 3 and the final exam, the gender gap has virtually disappeared, with women's average score essentially equal to that of men. Note that the average homework score of women, 92%, was not very different than the 90% for men. Perhaps if we can understand the causes of this gender effect, we may be able to better address the needs of other learners who have had less success in science courses.

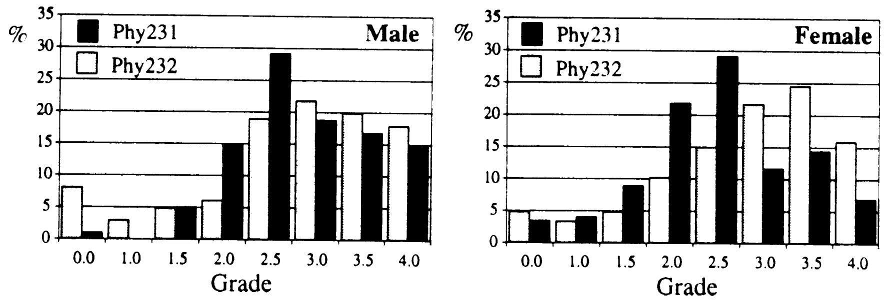


Figure 3: Grade distributions for males and females for the a two-semester course (Phy23l and Phy232). Phy23l was taught the traditional way and in Phy232 CAPA was used.

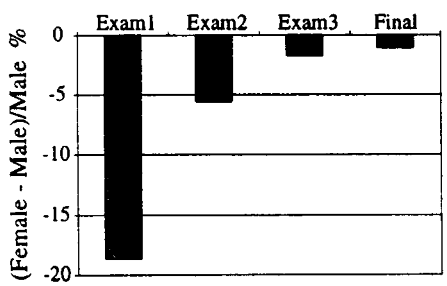


Figure 4. Relative difference between female and male performance on exams in Phyl83.

We have also studied factors correlated with performance on the final exam for the Fall 1999 and found them consistent with earlier results [8]. Correlation with quizzes ($r = .660$, $p < .001$), midterm exams ($r = .716$, $p < .001$) and homework ($r = .360$, $p < .001$) are all strong. Attendance in class is also an important factor relating to performance on the final, with absences negatively correlated to final exam performance ($r = -.374$, $p < .001$). To allow for the fact that these correlations could be driven by intelligence level (i.e., smarter students do better on homework and better on the final), we recomputed these correlations partialling out the students' composite ACT scores. The partial correlations were very similar to those presented above, and all remained statistically significant.

The preparation and testing of questions and problems that make up much of the formative and summative assessment content remains a significant task. In physics, several instructors have developed such materials and have tested and refined them over the years. Libraries of problems and questions, as well as a broad range of animations and simulations are available. A similar situation exists for chemistry, and such materials are being developed for other disciplines. Several publishers now have a large fraction of the problems in their physics texts coded for CAPA. However, the effort required when first implementing an ALN in a new discipline can be very large in spite of great progress in facilitating the use of technological tools. This is especially true when the new opportunities offered by technology are used to do more than deliver traditional materials in a new and efficient method.

Conclusions

In comparing educational effectiveness, one may need to differentiate between technology-mediated learning and technology-enhanced learning. We have demonstrated a continuing improvement in student achievement when network technology is used to complement and enhance on-campus courses. More students succeed and excel. Prompt feedback and student time on task rank high among contributing factors. One issue that needs to be addressed is the negative impact of student-created web sites that allow students to nominally succeed on assignments in the absence of actual learning. This difficult issue requires a solution that does not infringe on students' freedom to communicate. Another challenge for the future is the need to develop improved discipline-specific standards. Such standards would be of great help in assessing educational effectiveness more objectively, and could also lead to a better understanding of how educational materials can be developed or adapted to better take advantage of the technology.

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