Group Decision and Negotiation **8**: 371–384, 1999

Impact of Asynchronous Learning Networks in Large Lecture Classes

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Abstract

The evolution of the computer-assisted personalized approach (*CAPA*) system and its use in large lecture classes is described. Increased individual student contact in these large classes of over 400 students has been established by implementing an asynchronous learning network (ALN). The two systems complement each other and provide the means to monitor and promote individual student performance at any time during the semester. During one semester poorly performing students were individually contacted by personalized e-mail to inform them of their standing and to encourage better performance. Results of this combined technological approach are presented.

Key words: asynchronous learning networks, CAPA, computer assisted homework systems, technology in traditional lecture classes

1. Introduction

Enrollment in introductory classes at large universities often numbers in hundreds of students. Students lack personal attention and many have difficulty adjusting to this anonymous environment. This often contributes to poor performance (Cheatham 1994). Five years ago, an assignment system using a computer-assisted personal approach (*CAPA*) was developed at Michigan State University to address some of the concerns associated with large classes (Kashy et al. 1993). These problems include, but are not limited to, (i) the large manpower necessary to grade student assignments, (ii) a lack of a reward system for a student achieving success, (iii) the ability to track and maintain attendance records passively, (iv) the impersonal nature of large lecture courses, and (v) difficulty maintaining examination security. *CAPA* is also being used in smaller lecture classes but the main advantages are apparent in larger classes, where individual contact with each student is difficult to achieve.

The system was initially designed to generate individual homework assignments for physics classes, based on modern but widely available technology. Other systems have been developed which share many features with *CAPA* with one important difference represented by the handling of qualitative and conceptual questions (see for example Abbott 1991; Connell 1994; Weinstock 1995; Mallard 1997; Chiu and Moore 1993; Hubler and Assad 1995; Lewis et al. 1991; Mellema et al. 1993). In the years since *CAPA* was initiated, it has developed into a powerful tool that can be used in many aspects of a class. Its use is not limited to physics or even natural science classes and it has been applied to other disciplines including Human Nutrition and Computer Science. Many tools have been developed which facilitate the creation of conceptual questions allowing other disciplines to easily utilize this tool. The system was used here to generate individualized examinations and quizzes. Quiz dates were unannounced to the class and hence served as a passive record of attendance. *CAPA* is a tool which can be integrated into an asynchronous learning environment. We have recently combined its use with an asynchronous learning network (ALN). ALNs are primarily used in distance learning environments and they also have been found to be a very useful complementary tool for traditional on-campus classes (ALN 1997). An ALN is a natural extension of *CAPA*. It allows students to obtain help with homework problems and to access group discussions independent of any constraint which might be present due to employment or class schedules.

The database created in each system (*CAPA* and the ALN) provides the instructor with a wealth of information about each student. The performance of each student in homework, quizzes, exams, and attendance as well as participation in the ALN can be assessed at any time. The same information is available to the students each time they login so they are aware of their performance. In addition, we are developing tools to automatically contact students on an individual basis. This would otherwise not be practical in classes with well over 100 students. Some of the recent use and latest development of *CAPA* will be described in Section 2, the results of the first experience with the ALN will be discussed in Section 3 and the application of the database to enhance student performance is in Section 4.

2. *CAPA* Development

CAPA is a tool to write and distribute personalized assignments, quizzes and exams. Each student listed in the classlist file receives an individualized assignment for homework. This homework problem set relies upon random number generators to choose a set of variables, which are incorporated into the question text and ultimately determine the individualized answer. The same method is used for personalized examinations. This randomization within problems, and the ability to randomly choose which problems are presented to the student, eliminates the benefit of student copying during examinations. Students can use either VT100 terminal emulators or the WWW to enter answers. With *CAPA* students get several tries to solve problems without penalty. They receive immediate feedback from the computer on their attempts. This moves the role of performance judge

to the computer, allowing the instructor and teaching assistants to emphasize a mentoring role. The initial experience in physics and chemistry has been highly positive and is described in several publications (Thoennessen and Harrison 1996; Kashy et al. 1993, 1995).

The use of *CAPA* is not limited to physics, chemistry and mathematics. At MSU it is being used in Family and Child Ecology, Botany and Plant Pathology, Human Nutrition and Food, Biochemistry and Computer Science. At the present time (September 1998) *CAPA* has also been licensed to over 30 universities and colleges (CAPA 1998). An important feature of the system is the preparation of printed individual assignments, which includes all data necessary for completing the assignment. This allows students to interact with fellow students in group discussions while working their assignments rather than isolating them in front of a terminal screen. The group discussions provide for interesting social contacts while at the same time promote learning (Treisman 1992). Students who understand the concepts learn by helping their fellow students who also benefit from the interaction. This is especially true for conceptual problems making use of random labeling such as the one presented later in Figure 3.

The students' approval of *CAPA* continues to be high, even though they devote substantially more time to their work. As one student simply put it: "It takes more time because I correct my mistakes." Recently a study to compare the workload of students in a class using *CAPA* to a traditional class was performed (Thoennessen and Harrison, 1996). An introductory physics sequence for science/pre-med majors was taught in the traditional way for the first semester (PHY231) and with *CAPA* in the second semester (PHY232). In a questionnaire at the end of the second semester the students were asked how much time per week they spent on average on their homework for these two classes. The average weekly time was 5.7 hours for PHY232 (using *CAPA*) compared to 3.3 hours for PHY231 (without *CAPA*), which is a significant increase. Figure 1 shows the additional hours worked in PHY232 as a function of the students' assessment of the benefits of using *CAPA*. The average ranged from 1.7 additional hours for the students who were indifferent to 7.3 hours for the students who rated *CAPA* quite negative. The students who rated *CAPA* to be quite helpful worked an extra 2.4 hours on the average.

The few students rating the system "Quite Negative" all appeared to require an excessive amount of work to solve the problems. Discussions with three of these students who identified their negative feelings revealed that these were hard working students unable to achieve the course goals. Note however, there were many more students working just as many long hours who rated the system as "Quite Helpful".

Even after several years of use the students' approval rating of *CAPA* is remarkably high. By the time the students enter the physics sequence at MSU essentially 100% have heard of or have used the system in other classes. In one particular questionnaire at the end of an introductory physics class with 144 responses, 48% of the students rated *CAPA* quite helpful, 35% somewhat helpful, 8% were indifferent, 4% rated it somewhat negative and 5% quite negative. This is a typical response and has been repeated in many different classes. Another questionnaire (130 responses) asked for the reasons why students like *CAPA*. The top five reasons mentioned were: instant feedback (55 students, 42.0%), multiple chances (51 students, 39.5%), learn from mistakes (44 students, 34%), hints helpful (20 students, 15.5%) and helps grades (13 students, 10.0%). The total percentage

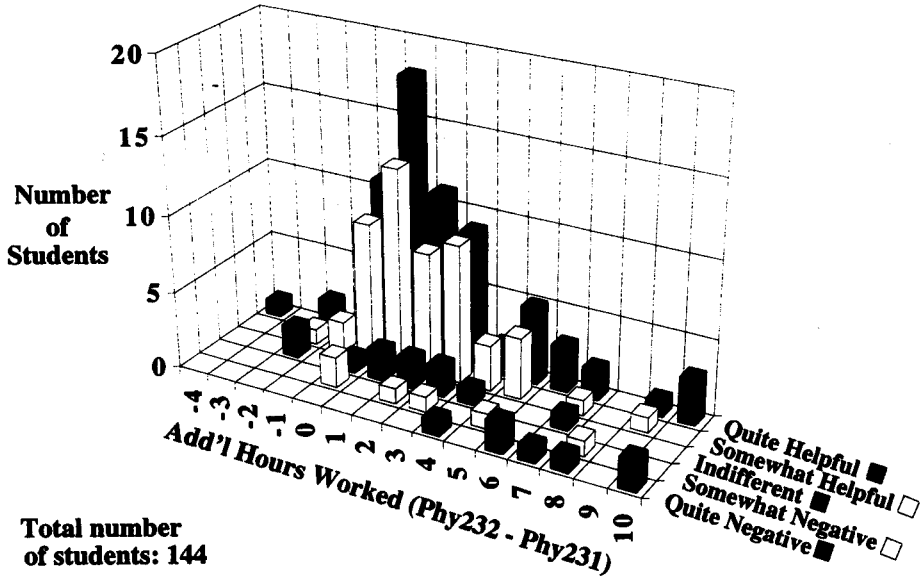


Figure 1. Three-dimensional display of the additional hours worked in the *CAPA* class (PHY232) compared to the traditionally taught class (PHY231) as a function of approval rating of *CAPA* by the students (adapted from Thoennessen 1996). Negative numbers indicate that some students actually worked less in PHY232 (with *CAPA*) compared to PHY231 (without *CAPA*).

is over 100% because some students gave more than one reason. One of the important features of *CAPA* is the versatility of conceptual problems (Kashy et al. 1995). Figure 2 demonstrates the capability of *CAPA* for individualized conceptual problems. The left side shows the question for one student, whereas the right side shows the same question for a different student. As can be seen from the differences all options can be randomized and scrambled. In addition the instructor has the option of having several choices for each of the items in the left column. Coding of such a problem with the basic built-in functionality would represent a rather complex task; however, *CAPA* provides templates for these conceptual question types, making the task straightforward.

Another example is shown in Figure 3. In addition to the randomization of the labels in the figure the statements appear in random order and each statement can be phrased in several ways. The number of different versions of this type of question is extremely large. Simple copying of the solutions from another student is essentially useless and two students collaborating have to work actively together in order to solve the problem. An important aspect of coding such a question is to ensure that all students are presented with the same set of concepts over which they may be tested.

In addition to the homework sets students had access to many supplementary problems. These problems were generated to further understanding, to allow for extra practice, and for exam preparation.

Kashy, Ed **Section 1**
Sample CAPA *Questions* *Set 1*
nsc111f7 -MSU- Due Fri, January 16, 1998 at 08:00
CAPA ID is 6352

4. [1pt] Match each person with the most appropriate description. (If the First corresponds to B, and the next 6 to C, Enter BCCCCCC)

1) Woodrow Wilson	
2) Elizabeth Browning	A. Painter
3) Socrates	B. Philosopher
4) Emanuel Kant	C. Politician
5) Andrew Mellon	D. Poet
6) John Keats	E. Philanthropist
7) Leonardo DaVinci	

Thoennessen, Michael **Section 1**
Sample CAPA *Questions* *Set 1*
nsc111f7 -MSU- Due Fri, January 16, 1998 at 08:00
CAPA ID is 7727

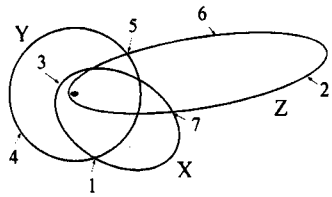
4. [1pt] Match each person with the most appropriate description. (If the First corresponds to B, and the next 6 to C, Enter BCCCCCC)

1) Harry S. Truman	
2) Claude Monet	A. Poet
3) Andrew Mellon	B. Politician
4) Elisabeth Browning	C. Philosopher
5) Socrates	D. Philanthropist
6) Plato	E. Painter
7) John Keats	

Figure 2. Example of a multiple choice question. Both columns are randomized.

Davis, Nancy **Section 2**
Sample CAPA *Questions* *Set 1*
nsc111f7 - MSU - Due Fri, January 16, 1998 at 08:00
CAPA ID is 3654

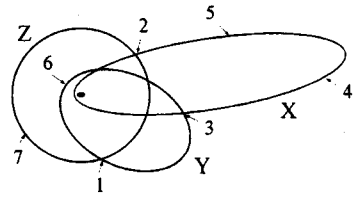
5. [2pt] Asteroids **X**,**Y**,**Z** have equal mass (9.0 kg each). They orbit around the planet with $M = 4.0*10^{24}$ kg. The orbits are in the plane of the paper and are drawn to scale.



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**.

Tsai, Isaac **Section 2**
Sample CAPA *Questions* *Set 1*
nsc111f7 - MSU - Due Fri, January 16, 1998 at 08:00
CAPA ID is 1656

5. [2pt] Asteroids **X**,**Y**,**Z** have equal mass (5.0 kg each). They orbit around the planet with $M = 3.0*10^{24}$ 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 3. Example of two versions of the same problem for two different students.

3. First Results of the ALN

As *CAPA* continued to evolve during the years it became obvious that the courses would benefit from the use of a full Asynchronous Learning Network. Typically these ALNs consist of a network system, where students can interact with the instructor as well as with other students "anytime, anywhere".

The first large-scale incorporation of ALNs for on-campus classes was performed at the Sloan Center for Asynchronous Learning Environments (SCALE) at the University of Illinois at Urbana-Champaign (SCALE 1997). Their results are extremely promising and they show an improvement in learning and efficiency. We selected FirstClass® by SoftArc as the ALN software (First Class 1997). In addition to a bulletin board and mail capability, it also had the option of online chats. The client software was distributed to all 2000 computers (PC compatible and Macintosh) on campus. The students could also download the client software via the WWW and install it on their own computers.

At MSU the ALN was added to *CAPA* for the first time in an introductory physics class for engineers with over 500 students. Undergraduate teaching assistants were online in the evening hours to answer questions. In addition, face-to-face help at the "Physics Learning Center" (PLC) was available and the PLC was staffed for about 20 hours each week. Initially most of the activity on the system was concentrated in the chats, which defeats an important purpose of an ALN. Students who login at different times do not benefit from these interactions. Apparently the students realized this deficiency and the number of logins dropped continuously during the first five weeks of the semester as shown in Figure 4.

It was obvious that initially only a small fraction of the students were using the ALN. The students were then encouraged to post their questions on the ALN rather than asking the questions during a chat session. The teaching assistants were instructed to give the highest priority to the posted questions. In addition, the instructor started posting hints (often in graphical format) on the ALN. The instructor also announced in class that further help was available via the ALN in order to stimulate its use. The content of the online help was determined by continuous monitoring of the degree of difficulty of each homework question presented in *CAPA*. If it was apparent that a problem was difficult for the students, the instructor addressed the topic again in lecture and explained the concept in a posted message on the ALN.

The number of students using the ALN increased dramatically at this point. The large fluctuations reflect the variation of difficulty of the homework sets. Week 12 was Thanksgiving and week 15 was the week before the final exam, when no homework set was given. Several students apparently used the information available on the ALN to study for the exam. Figure 5 shows the number of students who opened a message posted by the instructor. These messages were only posted starting in week 6 and the fluctuations again show the degree of difficulty of the homework set. For a relatively easy set no messages were posted (Week 8 and Week 13).

The database of the ALN contains a large amount of information about the study habits of the students. For example, Figure 6 shows the distribution of student logins as a function of time of the day. The peak in the evening hours can be explained by the availability of

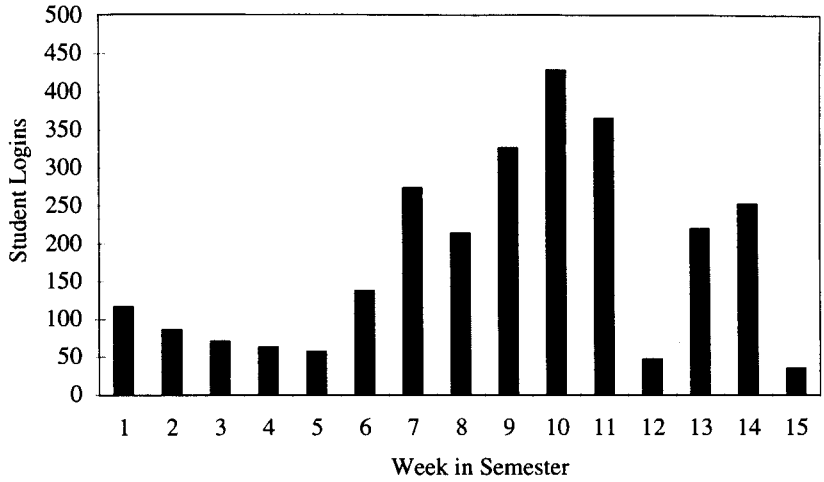


Figure 4. Number of students logged into the ALN during the semester.

teaching assistants online, when the students could get instant feedback and help. An even larger peak can be seen in the afternoon, when no teaching assistants were online. During these times the students relied on posted messages and online interactions via chats among themselves. This is even more surprising, considering that during these times the Physics Learning Center was open and students could get face-to-face help from teaching assistants.

52% of the students used the ALN. An analysis of their performance compared to the students who did not use the ALN was performed. Students who used the ALN performed

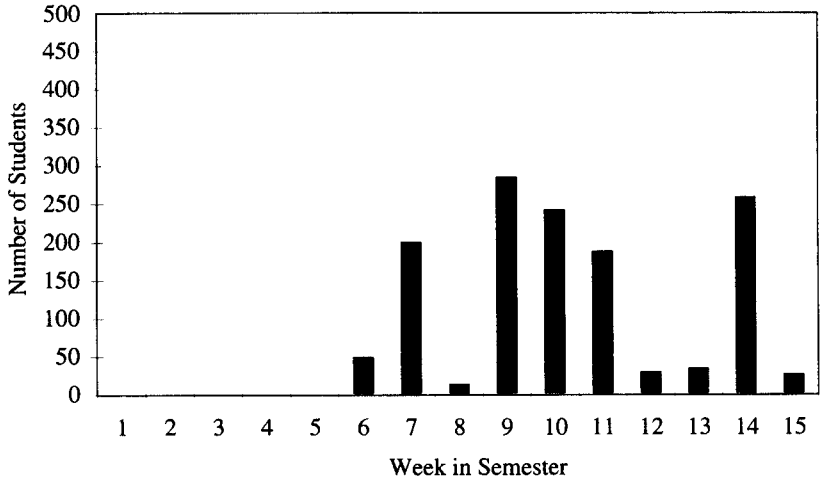


Figure 5. Number of students opening a posted graphics message.

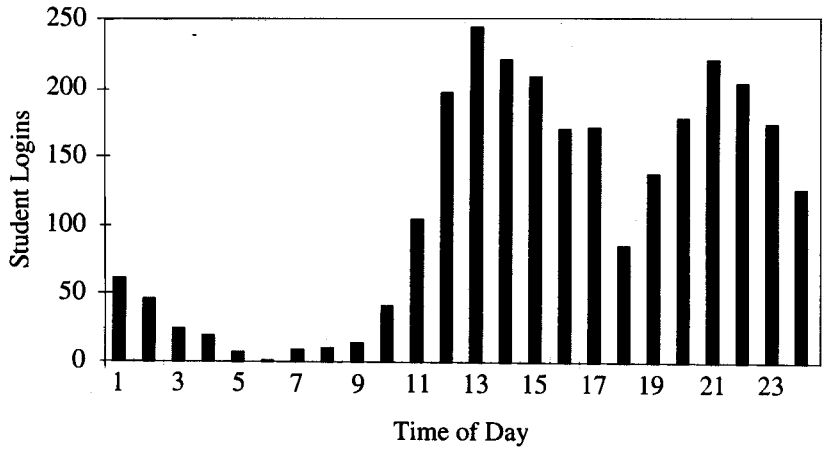


Figure 6. Number of logins as a function of the time of day.

10% better on the final exam, 5% better on the assignments, 11% better on the quizzes and they missed 12% fewer days in class. This is a marked difference between the performance of those students who did and did not use the ALN (Kashy et al. 1997).

However, this large effect cannot be ascribed to the ALN alone. Certainly the students electing to use the ALN may be better motivated and more actively seeking to learn. This is reflected in the negative correlation with "Days absent". The students who used the ALN attended class on a more regular basis. In the future we plan to monitor the students who are using the face-to-face help in the Physics Learning Center in order to compare the performances.

The influence of *CAPA* and the ALN on student performance is shown in Figure 7. In a class where *CAPA* was introduced recently the average exam performance by the students increased dramatically. The same instructor taught this class for the three years and exam performances of his classes are shown in the figure (Danielewicz 1996).

Figure 8 shows the evolution of the grade distribution from the traditional lecture course to a highly interactive environment using *CAPA*/ALN (Kashy et al. 1997). It also lists the percentage of students passing the course (grades between 2.5 and 4.0) as well as the drop-rate, which is defined as the percentage of students present at exam 1 but not at the final exam. The fraction of students passing the course increased while, at the same time, the drop-rate decreased.

4. Individual Student Contact via the ALN

The most recent development of our system takes advantage of the large database of information provided by *CAPA* and the ALN. Currently we continuously monitor student performance on the homework problems and thus have the opportunity to address areas of difficulty

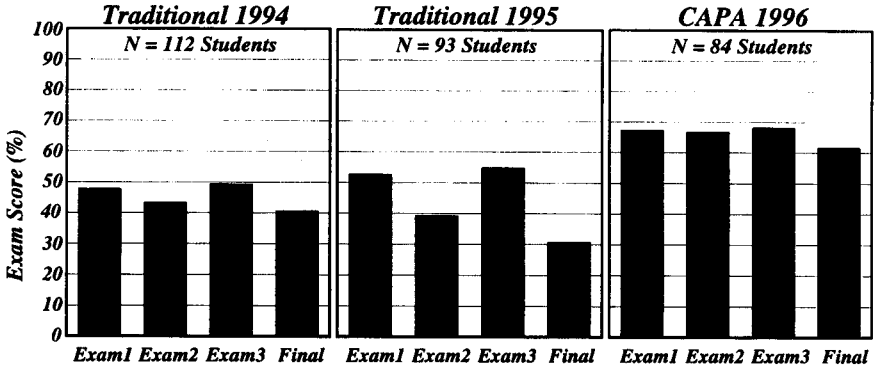


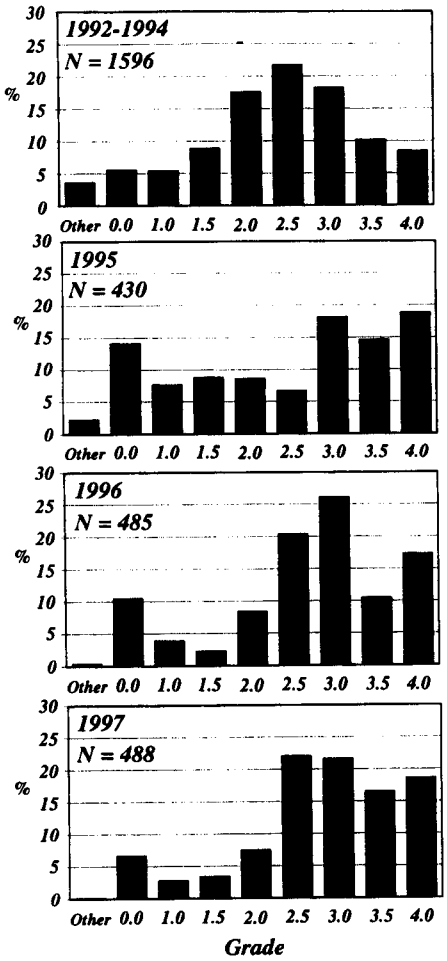
Figure 7. Comparison of the exam scores in an introductory physics course. In 1994 and 1995 the course was taught as a traditional class and in 1996 the same instructor used *CAPA*.

in lecture as well as through the ALN. We are developing several additional tools that take advantage of the information collected on various aspects of student performance. This information can then be communicated to the students directly with the help of the ALN.

The results of the homework, quizzes and the exams are stored in the *CAPA* database and thus are always up to date and available to the instructor. During the last semester this information was utilized in the introductory physics class for engineers where about 400 students were enrolled. In this class the final grade was determined from the homework (30%), quizzes (5%) (three) midterm exams (30%) and the final exam (35%). These ratios were programmed into a tool to calculate a projected final at any time during the semester. Another tool then generated individual messages that were based on the performance of each student. The following is an example of a message sent to one student:

Dear David,
You are enrolled in PHY184 and based on you current performance you will receive a grade of 0. You have solved 35.0% of the homework problems and you missed 1 of the 4 quizzes. Extrapolating from these data and from your exam 1 score of 19.5% your final percentage is projected to be 51.7%, which corresponds to a grade of 0. It seems that you have some difficulties with this course. Please contact me to discuss your situation and possible improvements either by e-mail (thoennessen@nscl.msu.edu) or by phone (5-9672, ext 323) to set up an appointment.
Regards,
Michael Thoennessen

The numbers and the name of the student were taken from the database. In this first application the individuality of the messages was limited to the first name and the standings of the student. In the last semester 100 messages (in a class of 400) were sent to students who were projected to receive a final grade of 1.5 or lower. In this particular class the students need a 2.5 in order to be eligible for engineering programs. The messages were sent approximately after the first third of the semester just prior to second exam. At this time the results of five homework sets, three quizzes and the first midterm were available.



	2.5 - 4.0	Drop-Rate At Exam 1 & Not At Final
1992-1994	59%	---
1995	58%	6.7%
1996	74%	4.5%
1997	78%	3.2%

Figure 8. Comparison of student performances for classes using *CAPA* /ALN and traditional classes. The final grade distributions for the average of three traditional classes (1992–1994) and the same course taught using *CAPA* and the ALN (1995, 1996, and 1997) is shown in addition to the passing percentage and the drop-rate.

53 students replied within a week requesting an appointment and/or explaining their poor performance and promising to improve. Almost all students were positively impressed by the detailed information given and by the personal tone of the message. A few sample of responses are "Thank you for showing your concern, it is not often a professor takes the time to help individuals", "Thank you for your concern, its nice to know that some professors do care", or, "I am glad that you made the attempt to contact me about my grade". They were mostly surprised that a professor in such a large class took the time to contact individual students.

All students replying indicated that they knew they were not doing well in the course. Most of them had an excuse for their situation and their message indicated a promise to perform better for the rest of the semester.

The following are two examples:

I am well aware of the fact that my grade in your class is very low. This semester I was sick for awhile (mostly flus and colds), and that made me lazy enough to stay in bed for your class time, and also away from the *CAPA* homeworks. However, I regret my behavior and promise you that I would do my personal best to pull my grade up from now on.

The quizzes are the result of some poor attendance on quiz days. (I really don't miss that much class. It just seems that every time I miss class you give a quiz. I'm making sure I make every class from now on to avoid more failed quizzes.) I am truly not a poor student but do have poor study habits.

Obviously not all of these students finished with a substantially better grade at the end of the term. This was the first time we attempted this approach and no follow-up messages were sent. Several of the contacted students attended classes more regularly for a while, but eventually stopped keeping up with the class. Perhaps with more reminders they would have responded better and achieved a passing grade.

Since all students who had a grade point average of 1.5 or below were contacted no direct control group was available. Figure 9 shows a preliminary analysis of the average final grade of the students as a function of the projected grade for all students. The overall correlation between the final grade and the projected grade is straightforward. Students who perform well at the beginning of the semester are likely to receive a high final grade.

To see whether contacting students had any impact, we compared the average final grades they earned to their projected grades. There is a small positive effect in that the average final grade for the students who were projected to receive a 1.5 is essentially the same as that for the students who were on a path to a 2.0.

The analysis of the present data should be taken with caution because they are only based on the experience of one semester and it is important to normalize them to data

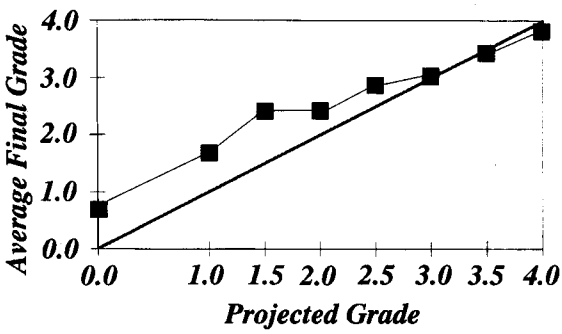


Figure 9. Average final grade versus the projected grade. Students with a projected grade of 1.5 or lower were contacted after the first five weeks of the semester.

of previous semesters where the students were not contacted and encouraged to improve.

The example of one particular student who was predicted to receive a 0.0 and responded to the message is shown in Figure 10. He improved in all areas after the e-mail message, but it took some time to partially catch up on the work that he neglected. We are currently expanding the tool to allow more options and flexibility. The wording of the sentences can be selected based on the performance criteria and data from each of the components, such as the homework, quizzes, and exams. In addition, the participation in the ALN, which is being monitored, will be included in the analysis and the students can be encouraged to participate and take advantage of the ALN.

As more fully developed tools become available, we plan to contact all students, those doing well in addition to those doing poorly with appropriate messages at least twice during the semester. We hope to see more students reacting like the example shown in Figure 10. Once the tools are developed and refined they take little time to apply and allow an efficient means to contact many students in a large class. Even if only a few students are helped by these interactions and achieve the goals, it is worth the effort.

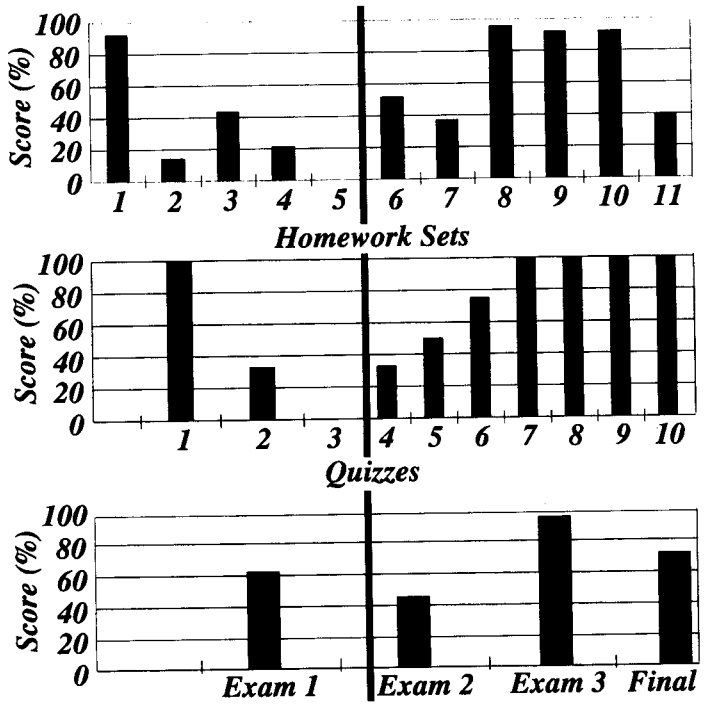


Figure 10. Performance of one student who was projected to achieve a 0.0 in the class. The projected grade was calculated after five homework sets and three quizzes just before the second exam.

5. Conclusions

We have implemented a computer-assisted personalized approach (*CAPA*) system that allowed us to give students in a large class individual homework assignments. These included quantitative as well as qualitative problems with strong emphasis on conceptual understanding.

CAPA by itself can be viewed as one crucial part of an ALN. The students can solve and check their problems "anytime, anywhere", instead of waiting for their problems to be graded by the instructor at a later time. The system continues to be developed to increase the versatility of conceptual and quantitative problems, to take advantage of the latest technology, and to make it easier for the instructor to use.

The addition of the ALN via FirstClass® added the interaction between students and the instructor as well as between students themselves. The use of the ALN was not intended to replace face-to-face interaction but to complement these interactions. The first experience shows that it is important for students to find useful information on the system and it takes encouragement from the instructor for students to login. It is anticipated that in the future an increasing number of students will see it as a very convenient, flexible and effective way to obtain help. In the future we plan to provide an ALN and the *CAPA* system on a single server, i.e. allow the student to access the ALN directly from the *CAPA* homework webpage. This should further facilitate instructor interaction with students and interaction among students.

The results of the attempt to contact students on an individual basis even in large classes are still very preliminary. Students were contacted only during one semester and although it seems to have a positive effect it remains to be seen if this approach is an effective way to enhance student success.

Overall our experience using computer technology in large lecture classes indicates that it can help improve efficiency and effectiveness and is highly encouraging. It has become clear that the use of network technology such as what we have described above can have a positive impact on learning not only in the subjective judgments of the students and their instructors (Wolfs 1995; Kashy et al. 1993, Morrissey et al. 1995), but also from objective results of test performances (Tsai 1994; Danielewicz 1996; Kashy et al. 1997).

Acknowledgement

This research was supported by the Alfred P. Sloan Foundation.

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