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Application of Technology and Asynchronous Learning Networks in Large Lecture Classes [1]

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Abstract

The evolution of the computer-assisted personalized approach (CAPA) system and its use in large lecture classes is described. Further 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 the individual student performance at any time during the semester. During the last semester poorly performing students were individually contacted with personalized e-mails to inform them of their standing and to encourage better performance. Results of this combined technological approach are presented.

1. Introduction

The 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 [1]. Five years ago, an assignment system using a computer-assisted personal approach (CAPA) was developed at Michigan State University to address some of the problems associated with large classes [2]. These problems include, but are not limited to, (i) the manpower necessary to grade student assignments, (ii) 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) maintaining examination security. CAPA is also being used in smaller lecture classes but the main advantages are apparent in larger classes, where the more individual contact with each student is difficult to achieve.

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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 Refs. [3-10]). In the years since CAPA was initiated, it has developed into a powerful tool which 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.

We have recently combined the use of CAPA 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 complimentary tool for traditional on-campus classes [11]. An ALN is a natural extension of CAPA. It allows students to obtain help with homework problems and to access group discussions independently 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 II, the results of the first experience with the ALN will be discussed in Section III and the application of the database to enhance student performance is in Section IV.

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 student copying during examinations. Both the homework sets and the examinations have the students name printed at the top. Quiz papers also contain randomly generated questions but are not distributed in the same fashion. The quizzes appear to the student to be completely generic and anonymous.

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 [2,12-14].

The increasing use of *CAPA* at MSU and at other universities and colleges until 1996 is shown in Figure 1. At the present time *CAPA* has been licensed to over 20 universities and colleges [15].

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. Classes in Biology, Microbiology, and Business Management are also planning to use this system for the next academic year. The growing use is due to the continuing development of a variety of problem styles that are incorporated into the system as shown at the end of this section. Coding of such problems is facilitated by numerous templates. *CAPA* is regularly upgraded to utilize the latest technology. It is accessible for student login 24 hours per day prior to the due date of each homework set. Initially student access was limited to VT100 terminals, an option which remains available. Recently students have been given the option to access the system via a WWW browser giving the instructor the means to provide links to material relevant to the concepts covered in a problem set. Interestingly, the majority of students at MSU prefer to enter their answers via telnet sessions and VT100 terminal emulators. We have found that students use the hard copy of their assignments in group discussions at the help rooms and learning centers, then wish to login and only enter their answers. The telnet sessions are extremely fast compared to the web interaction. Students accessing the system via slower modems appreciate the rapid response of the telnet sessions. In the spring semester of 1997 $\sim$ 80% of the logins were via telnet.

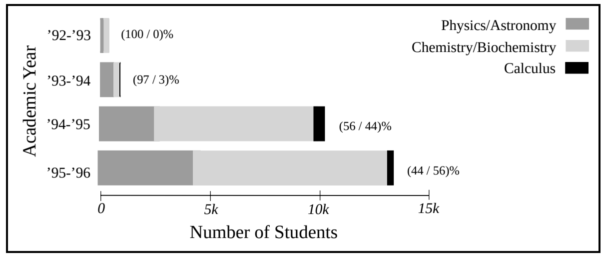


Figure 1: Use of *CAPA* until last year. The graph shows the use at Hope College, Ohio University, University of Rochester, SUNY at Stony Brook, Texas A&M University, Simon Fraser University, and Michigan State University. The numbers in parenthesis are the percentage of students at MSU and at other universities, respectively.

An important feature of the system is the preparation of printed individual assignments. This allows students to interact in group discussions while doing 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 promoting learning [16]. 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 labelling such as the one presented later in Figure 5.

The students' approval of *CAPA* continues to be high, although 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 [14]. 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 2 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.

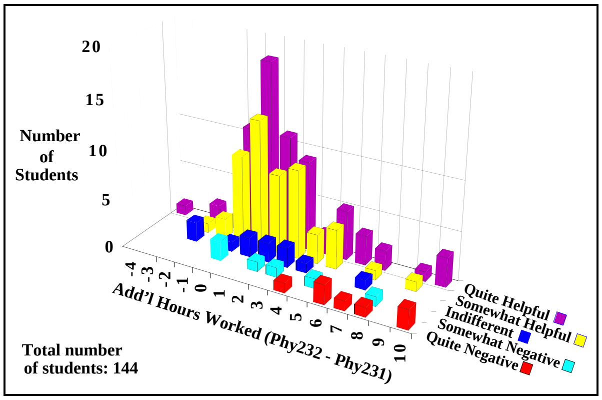


Figure 2: Two-dimensional display of the additional hours worked in the CAPA class (PHY232) compared to the traditionally taught class (PHY231) as a function of approval rating of CAPA by the students (adapted from [14]). Negative numbers indicate that some students actually worked less in PHY232 (with CAPA) compared to PHY231 (without CAPA)

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. Figure 3 shows a typical response of the students with respect to the use of CAPA.

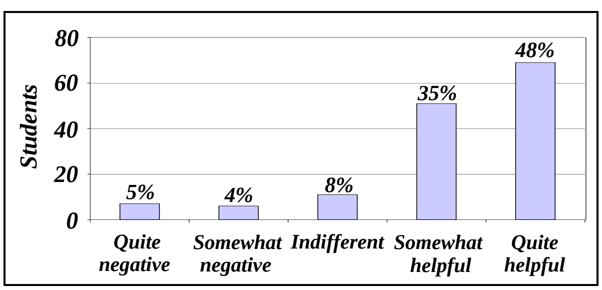


Figure 3: Typical rating of CAPA at the end of an introductory physics class.

One of the important features of CAPA is the versatility of conceptual problems [12]. Figure 4 demonstrates the capability of CAPA for individualized conceptional problems. The top part shows the question for one student, whereas the bottom part 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.

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

4. [2pt] 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) Elizabeth Browning	C. Philosopher
5) Socrates	D. Philanthropist
6) Plato	E. Painter
7) John Keats	

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

4. [2pt] 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	

Figure 4: Example of a multiple choice question. Both columns are randomized.

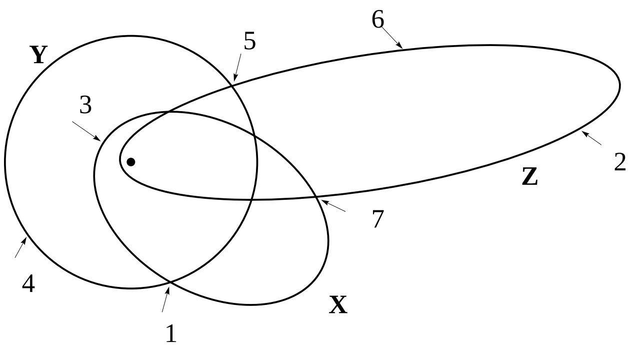
Another example is shown in Figure 5. In addition to the randomization of the labels in the figure the statements appear in random order and each statement can be phrased in several ways. Thus the number of different versions is extremely large.

Davis, Nancy **Section 2**

Sample CAPA Questions *Set 1*

nsc111f7 – MSU – Due Fri, January 16, 1998 at 08:00
CAPA ID is 3654

2. [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.



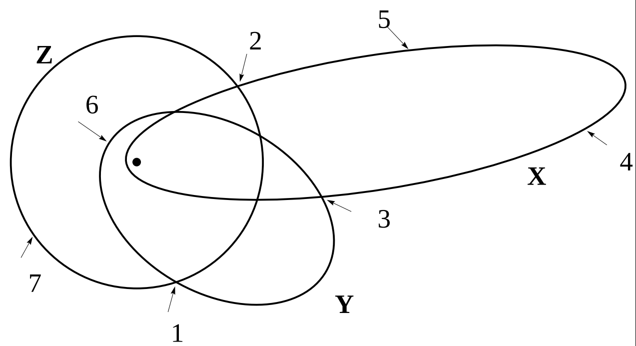
Select G-Greater than, L-Less than, or E-Equal to.
A) The angular momentum of **X** at 7 is .... that at 1.
B) At 5, **Y**'s angular velocity is .... that at 1.
C) The period of **X** is .... that of **Z**.
D) The angular velocity of **X** at 3 is .... that at 7.
E) **X**'s angular momentum is .... that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

Tsai, Isaac **Section 2**

Sample CAPA Questions *Set 1*

nsc111f7 – MSU – Due Fri, January 16, 1998 at 08:00
CAPA ID is 1656

2. [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: Example of two versions of the same problem for two different students.

Simple copying the solutions from another student is essentially impossible 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 concepts, as it would be unfair if an exam question tested a concept that was on an assignment of a fellow student but not on his.

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

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

3. First Results of the ALN

As *CAPA* continued to evolve during the years it became obvious that the system would benefit from the addition of a full Asynchronous Learning Network. Typically these ALN's 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 ALN's for on-campus classes was performed at the Sloan Center for Asynchronous Learning Environments (SCALE) at the University of Illinois at Urbana-Champaign [17]. Their results are extremely promising and they show an improvement in learning and efficiency. We selected FirstClass® by SoftArc as the ALN software [18]. 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. In addition to face-to-face help at the “Physics Learning Center” which was staffed for about 20 hours each week during the day, undergraduate teaching assistants were online in the evening hours to answer questions by the students via the ALN. Thus, 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 6.

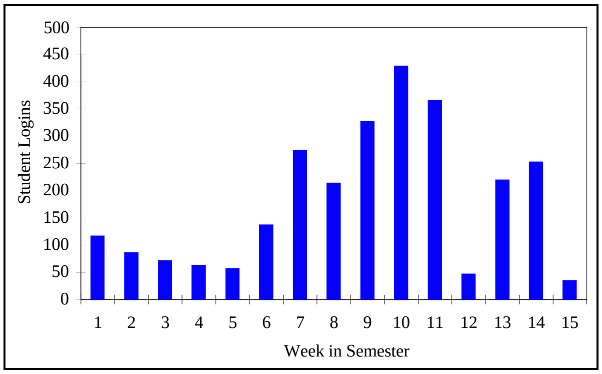


Figure 6: Number of students logged into the ALN during the semester.

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 the ALN use. The hints were initiated from the continuous monitoring of degree of difficulty of each homework question available on 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. Also, week 12 was Thanksgiving and week 15 was the week before the final exam, where no homework set was given. Still, several students apparently used the information available on the ALN to study for the exam. Figure 7 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 data base of the ALN contains a large amount of information about the study habits of the students. For example, Figure 8 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 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 where the students could get face-to-face help from teaching assistants.

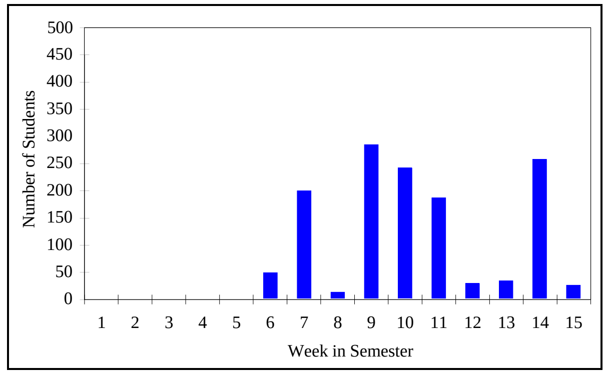


Figure 7: Number of students opening a posted graphics message.

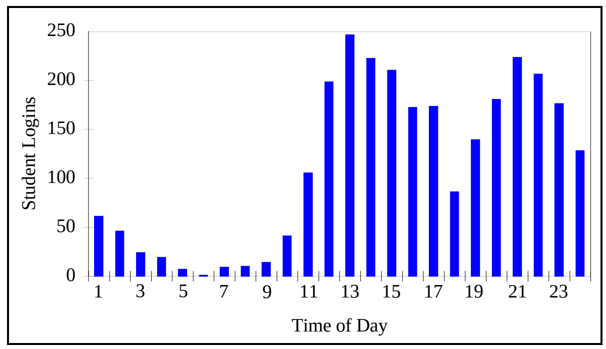


Figure 8: Number of logins as function of the time of day.

52% of the students used the ALN. An analysis of their performance compared to the students who did not use the ALN was performed. Table 1 shows a marked difference between the performance of these two groups of students [19].

Table 1: Performance of students using the ALN.

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

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 strong negative correlation with “Days absent”. The students who used the ALN attended class on a more regular basis. In the future we will 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 9. It shows the dramatic change of grade distribution from the traditional class to the class using CAPA and the ALN [19]. In another 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 [20].

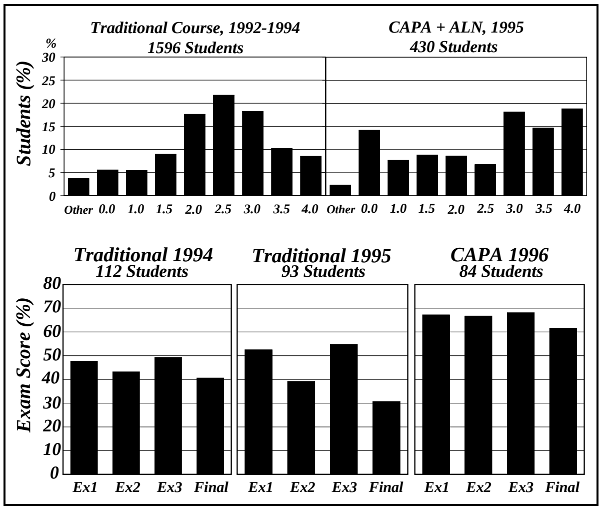


Figure 9: Comparison of student performances for classes using CAPA/ALN and traditional classes. The top panel shows the final grade distributions for the average of three traditional classes and the same course taught using CAPA and the ALN. The bottom panel compares the exam scores for a traditional class and a class using CAPA.

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 the student performance of the homework problems and thus have the opportunity to address areas of difficulty in lecture as well as through the ALN. We are developing several additional tools which 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. One example is shown in Figure 10.

Dear David,
You are enrolled in PHY184 and based on you current performance you will receive a grade of 0.0. 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 0.0.
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

Figure 10: Example of an computer generated message based on the students performance and the calculated projected grade.

The numbers and the name of the student were taken from the data base. In this first application the individuality of the messages was limited to the first name and the standings of the student. The e-mail addresses of all students were also stored in the database and these messages were sent automatically to the students. 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 before the second exam. At this time the results of five homework sets, three quizzes and the first midterm were available. 53 students replied within a week either 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 sample of remarks from student responses is shown in Figure 11. 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 some kind of an excuse for their situation and their message indicated a promise to perform better for the rest of the semester.

“Thank you for showing your concern, it is not often a professor takes the time to help individuals.”
“Thank you, it is helpful that a teacher cares as much as yourself.”
“Thank you for taking the time to notify me of my problem. Most teachers would not.”
“I am glad that you have made the attempt to contact me about my grade.”
“I truly thank you for your concern on behalf of my grade.”
“Thank you for your concern, its nice to know that some professors do care.”

Figure 11: Excerpts from student responses to the e-mail message about their performance.

A sample of replies are shown in Figure 12. 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.

“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.”
“ I too have noticed my performance in Phy 184 is lacking. I would like to try and finish the course this semester if possible.”
“I know I have not fared well so far, because of some personal problems, I have missed quite a few classes, and have not completed most of *CAPA* or quizzes, but I will make up for this as much as I can in the forthcoming exams and *CAPA*.”
“I am aware of my performance on the homework sets, I have had some personal problems which have prevented me form spending the needed time on them. I have recently resolved those problems therefore I should have more time for the homework.”

Figure 12: Excerpts from student responses regarding their poor performance.

Since all students who had a grade point average of 1.5 or below were contacted no direct control group was available. Figure 13 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 straight forward. Students who perform well at the beginning of the semester are likely to receive a high final grade.

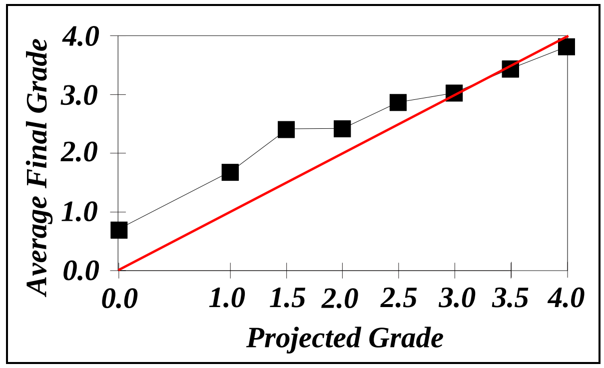


Figure 13: Average final grade versus the projected grade. Students with a projected grade of 1.5 or lower were contacted after the first five weeks of the semester.

To see whether contacting students had any impact, we compare the average final grades they earned to their projected grades. We can see 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.

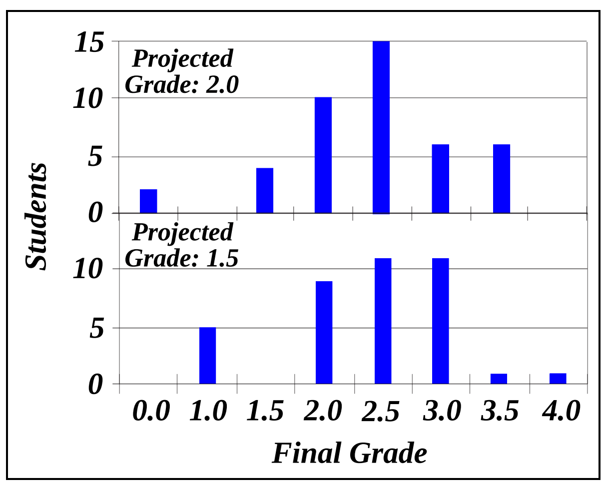


Figure 14: Grade distribution of students projected to achieve a grade of 2.0 (top) and 1.5 (bottom).

The distribution of final grades for the students with projected grades of 2.0 and 1.5 are shown in the top and the bottom of Figure 14, respectively. The two distributions look quite similar, indicating that the students who were contacted (projected grade of 1.5) showed more improvement compared to the students who were not contacted (projected grade of 2.0).

Figure 15 shows the difference between the final grade and the projected grade as a function of the projected grade. While the average of the higher projected grades is lower than predicted, the students predicted to have lower grades improved. Again, this effect is obvious for the lowest and highest grades because the students predicted to get a 4.0 can not improve and can only drop, while the 0.0 students can only improve. The improvement of the lowest three grades, however, is substantial.

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

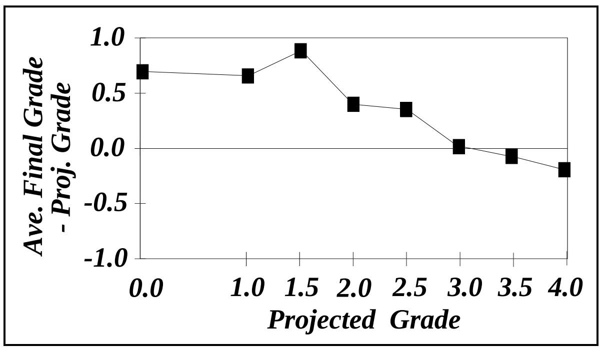


Figure 15: Difference of final grade minus the projected grade versus the projected grade.

The example of one particular student who was predicted to receive a 0.0 and responded to the message (see Figure 10) is shown in Figure 16. 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, etc. 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.

With the fully developed tools available for the next semester, 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 Figures 8 and 16. 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.

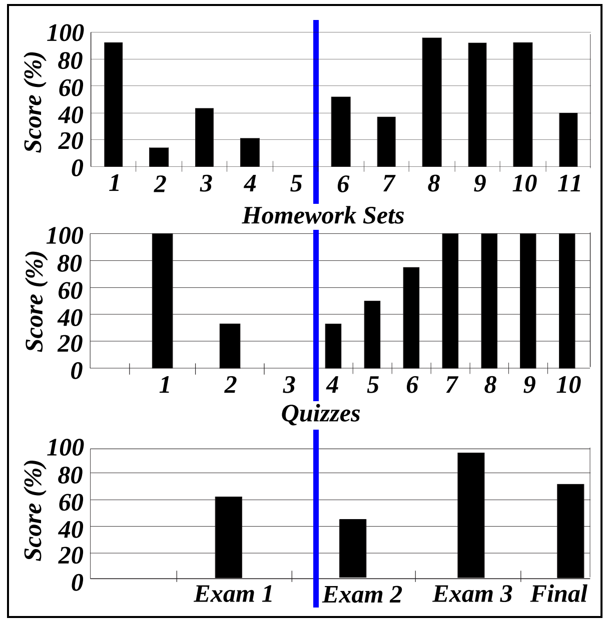


Figure 16: Performance of one student who was projected to achieve a 0.0 grade (see Figure 10) in the class. The projected grade was calculated after five homework sets and three quizzes just before the second exam.

5. Conclusions

We have implemented a computer-assisted personalized approach (*CAPA*) system which 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” in an asynchronous mode, 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 the use for the instructor easier.

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 that the students 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 increasingly greater 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 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 it can help improve efficiency and effectiveness and is highly encouraging. It has become clear that the use of networking technology such as that we have described above can have a positive impact on learning not only in the subjective judgements of the students and their instructors [2,13,21], but also from objective results of test performances [19,20,22].

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Key to Multiple Choice problems:

Figure 4: Version1: BEDACCA Version2: CDBBEDA
Figure 5: Version1: EELGLEG Version2: LGGEEEL