Preprint accepted for publication in Computers and Education

Computer-Assisted Assignments in a Large Physics Class

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The *CAPA* system, a software tool to implement a **C**omputer-**A**ssisted **P**ersonalized **A**pproach for homework assignments and examinations, was used in large introductory physics class for the first time. The students rated the system extremely favorably even though they spent significantly more time on the assignments compared to traditional classes. Fewer teaching assistants were needed and their time could be diverted from grading to more interactive contact with the students.

1. Introduction

The use of computers in education is very widespread. There are many interesting and effective tutorials and simulations to reinforce classroom concepts. In laboratories, computers have been integrated in the experiments, data acquisition and analysis [1]. For lecture courses several different computer programs have been developed independently to generate individualized homework assignments for physics classes (see for example [2–7]). At Michigan State University the *CAPA* system was introduced for the first time three years ago [8]. *CAPA* has some common features with the other computerized assignment systems but it represents a significant advance in using modern technology. Its convenient access, simplicity of use, immediate feedback, and emphasis on learning vs. grading and ranking has resulted in a very high level of student acceptance. In order to reduce costs and guarantee easy access, the student hardware requirements are very low.

CAPA is based on three software modules which create individual homework assignments for each student. Although the basic concepts of the problems are the same for all students, the numerical values are different for each student. In addition multiple choice problems have N-correct out of M-choices, where the number N is unknown to the students and can vary for different students. The order of the M-statements is randomized and the text of each statement can even be varied. Such problems help the students to clarify common misconceptions and have them share their understanding [9]. The students then have the opportunity to type their answers into one of the many computer terminals on campus or via their own computers equipped with modems, and thus can get immediate feedback from the computer as to whether the solution is correct or incorrect. They have unlimited tries to solve the problems and there is no penalty for incorrect answers. The automated grading frees up human resources that can be used for additional personalized attention toward the students. The instructor is viewed as a friend and helper and not as the grader or judge. A more detailed description of the system can be found in Reference [8].

So far the system has been used for three semesters in an introductory physics class for non-science majors of about 70 students [8] as well as in an introductory chemistry class [10]. We report here on the first experience in a large introductory physics class (> 300 students) of science/pre-med majors. The class material was electricity/magnetism, optics and modern physics as the second part of the introductory physics sequence. The first semester, mechanics and thermodynamics, was taught in the traditional way. It was thus possible to get evaluations of *CAPA* from students who were exposed to both *CAPA* and non-*CAPA* classes in physics. Such evaluations were not available in the previous experiences with *CAPA* for non-science majors [8].

2. Class Set-up and Office Hours

The lectures were divided into two sections of ~ 240 and ~ 120 students taught by different professors. There were no statistically significant differences in the performance or the evaluations between the two sections. The students picked-up their *CAPA* homework sets on Fridays before the lectures with the computer deadline at 8:00am on Fridays of the following week. Since the use of the computer was optional, the students could alternately hand in their homework before the lecture. Twelve homework sets with a total of 196 problems were given. The final grade was determined by the homework (35%), two midterms (15% each) and a final exam (35%).

In addition to using *CAPA*, the class differed from typical classes in another important way: there were no traditional recitation sections where sample problems were typically solved by the teaching assistant or selected students. Instead of the recitations, a total of 34 office hours were offered, spread over the whole week, at many different times. A large fraction of the office hours was concentrated during the last two days before the deadline. Sometimes even two parallel sessions were offered. These later office hours were the most heavily frequented with about 10-15 students attending. Only in special cases where one problem was of interest for the majority of the students did the instructor explain the concept on the board. Otherwise he gave hints and explanations to smaller groups of 2-3 students at a time. It was very interesting to see that while he was working with some students others would interact and help each other, and this was greatly encouraged. In several cases it was observed that a student who had solved all his/her problems stayed to help others.

The large number of office hours and individual attention for the students were possible because the office hours were essentially the only responsibility of the teaching assistants. Almost all the grading was automatically performed within the *CAPA*-system, since only a few students did not use the computer to enter their answers to the homework problems. On the average $\sim$ 10 students returned their homework on paper to be graded by the teaching assistants. This took less than 30 minutes. The class actually used fewer TA's than normal classes of the same size. In addition to the two professors lecturing the two sections only two graduate students on a quarter-time assistantship (10 hours/week) were working on the course. Previously this class would have used 4 teaching assistants to grade homework and teach the recitation sections. The large number of office hours turned out to be an important feature for using *CAPA* because

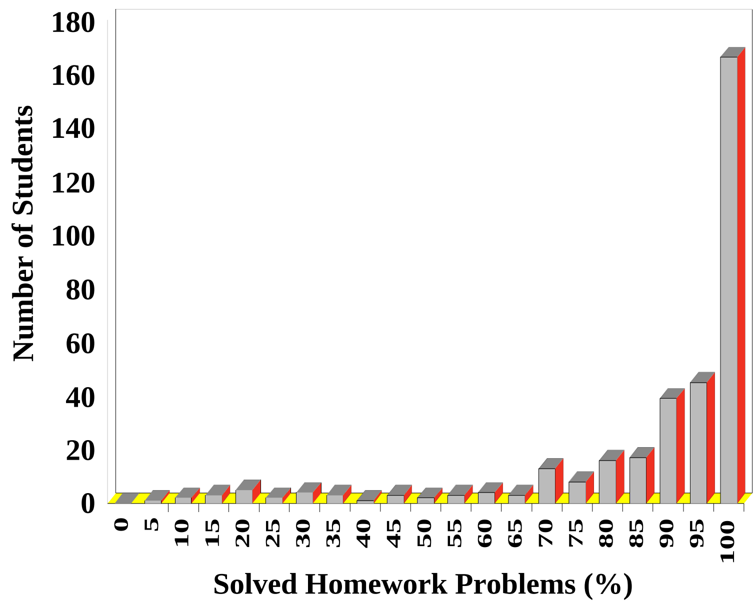

Figure 1. Distribution of solved homework problems in % for the whole class.

it significantly increased the personal interaction between the professors, teaching assistants and the students.

3. Student Performance

The majority of the students worked hard to solve all of their problems. The distribution of solved homeworks for all 196 problems is shown in Figure 1. It peaks sharply at 100%, even more so than the distribution of non-science students in the first *CAPA* class [8].

Although there were a few students who came to the office hours unprepared, seeking to get the answer as quickly as possible without understanding the problem, the relatively large weight (35%) of the homework toward the final grade was not the only motivation to get a score of 100% in the homework. The students were given five "free" problems, i.e. all the scores above 191 (out of 196) counted as 100% for their homework grade. A large fraction of the students came during the last week even though they were already above this limit. The satisfaction to see the computer display all 196 'Y' for all correct answers was apparently quite a motivational factor.

There is a clear correlation between the homework performance and the results of the final exam. Figure 2 shows the average score on the final in % as a function of the homework performance. Students who solved all the homework problems performed significantly better in the exam than the students who did not do, or only rarely did, their homework. Figure 3 shows the detailed correlation of the student distribution as a function of their homework and final exam performance. The majority of the students are localized in the upper left triangle of the distribution, which means that the homework percentage was higher or equal to their score in the final exam. Only a few students performed better in the final than in the homework.

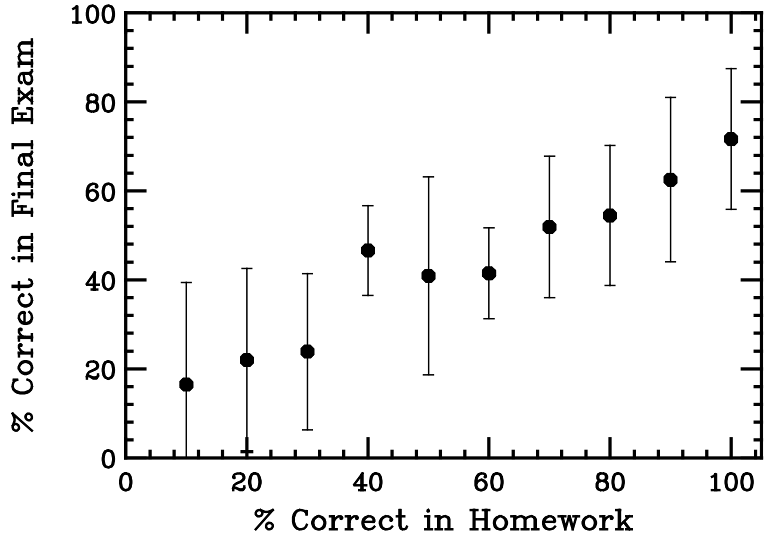

Figure 2. Average performance in the final exam (in %) as a function of the fraction of homework problems solved (in %). The error bars correspond to the width of the distribution (σ).

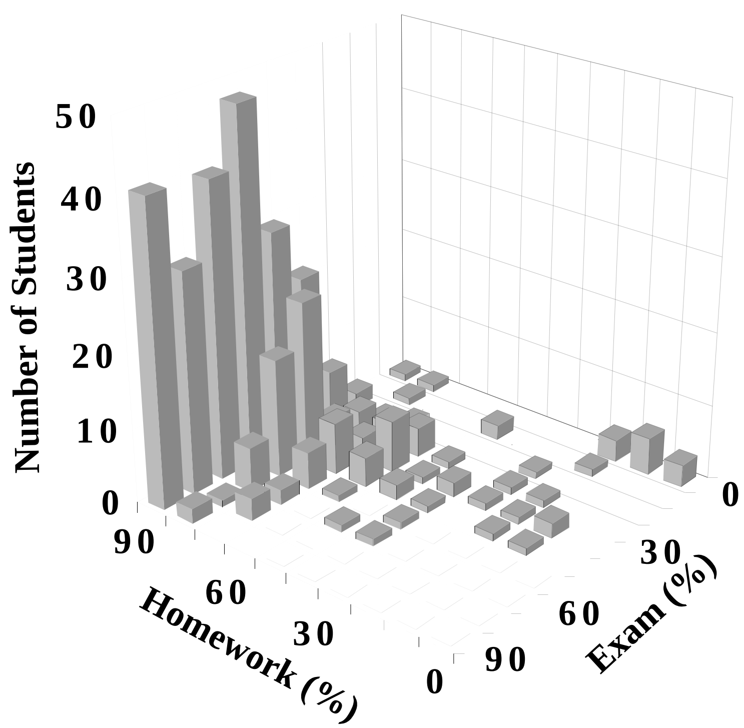

Figure 3. Correlation between the percentage of solved homework problems to percentage correct on the final.

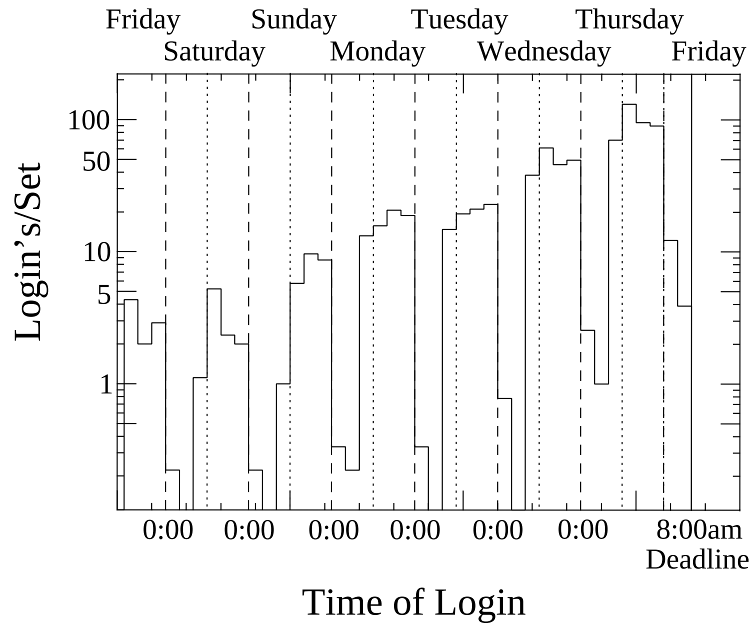

Figure 4. Total number of logins per set as a function of time after they were handed out in class until the deadline, Friday, 8:00am. The dotted and dashed lines represent noon and midnight, respectively.

4. Feed Back for the Instructors

There was immediate feedback from the system available to the instructor from the logins and answers of the students which were saved and continuously updated. The number of logins per set and the cpu-minutes used by the class each day until the deadline were essentially the same for the present class as previously reported for a chemistry class [10].

Figure 4 displays the number of login's per set averaged over the whole semester as a function of time for the first section of the class. In this semilogarithmic plot it appears that most of the students wait until the last day to solve the problems and check their answers. This was consistent with the large number of students utilizing the last office hours (The last office hour ended at 7:00pm and the teaching assistant had a hard time getting home). In order to diffuse the strong peak of logins near the end the deadline was set at 8:00 am. On the average around 10 students stayed up quite late in order to solve a homework set. It is also interesting to note that the majority of the students worked in the afternoon (and only a few in the morning) with a large fraction working until midnight.

The number of students who solved a particular problem could also be monitored while the students worked on the problem. This information is very helpful in finding possible misconceptions and difficulties that the students might have with a particular problem [11]. The instructor can then react and address these problems again in class before the deadline of the problem set. The top panel of Figure 5 shows the average homework score in % for all twelve homework sets for the first section of the class. The first homework set, which was designed to introduce the students to the system was solved by more than 90% of the students. The students obviously had a much harder time with the second set. Thus the figure seems to

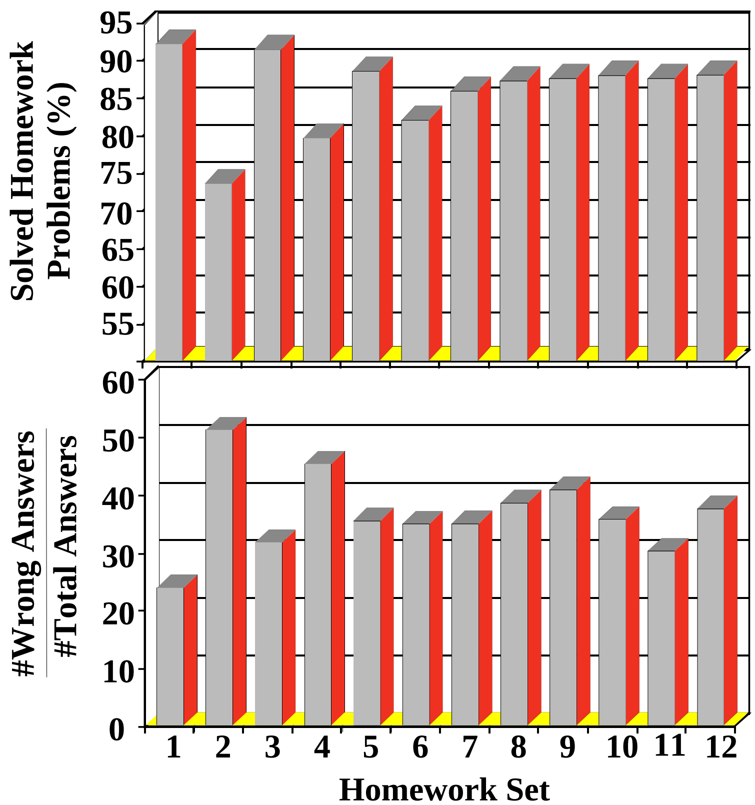

Figure 5. Average number of solved problems (in %) (top) and degree of difficulty defined as the ratio of number of wrong answers over the number of total answers (bottom) for the twelve homework sets.

indicate that the second, fourth and sixth homework sets were the most difficult. However, a much better measure of the degree of difficulty for a set is shown in the bottom panel of the figure. This shows the ratio of incorrect answers over the total number of tries in %. The figure confirms the fact that set 2 and set 4 were the most difficult for the students to solve. The figure also reveals that the last six sets were not of equal difficulty; this could have been inferred from the constant $\sim 85\%$ of solved problems for those sets. For example, although the same number of problems were solved eventually in sets 11 and 12, the student needed more tries in set 12.

This statistic was also available for each individual problem and was extremely useful for the instructors. After the homework was distributed and the students started solving the problems, the instructors could monitor this ratio and thus identify individual problems that were difficult for the students to solve. Lectures were then modified to address the underlying concepts for those problems. Figure 6 shows the ratio of wrong answers to the total numbers of tries for all 196 individual problems. It displays the wide spread of difficulty of the problems. The group of apparently easy problems between 160 and 170 were review questions at the beginning of the eleventh set.

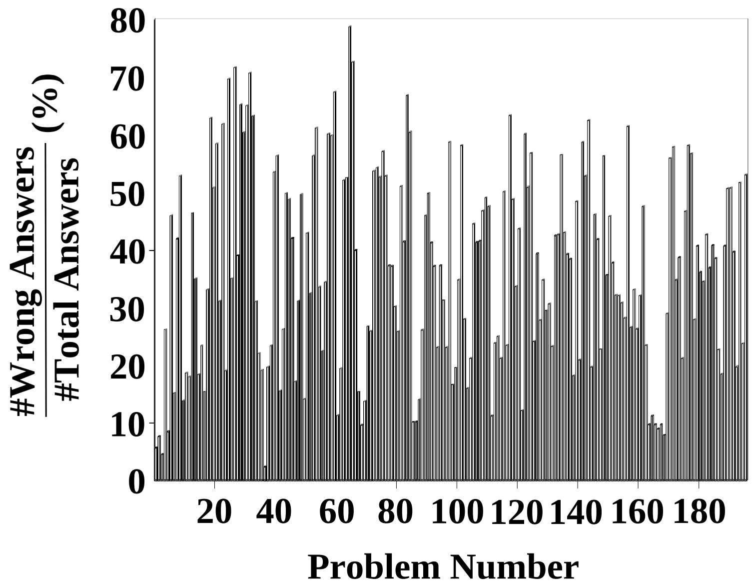

Figure 6. Degree of difficulty, expressed as the ratio of number of wrong answers over the number of total answers for all 196 individual problems.

5. Student Response

In the middle of the term a questionnaire was given to the students to receive feedback about *CAPA*. As in previous classes where *CAPA* was used, the system was rated extremely positive by the students [8,10]. In the present case most of the students had been enrolled in the first semester of the sequence which was taught in the traditional way. Thus they could compare their experience with *CAPA* directly to a standard physics class. 83% of the students rated *CAPA* as either very helpful or helpful as listed in Table 1 with only 9% giving it a negative rating. This positive approval of *CAPA* is even higher than the positive ratings of other computer aided systems [3], see also Ref. [9].

Table 1
Additional Hours worked in the *CAPA* class for different assessments of the system by the students.

# of Students	%	Assessment	Add. Hours
69	48	Quite Helpful	2.4
51	35	Somewhat Helpful	2.0
11	8	Indifferent	1.7
6	4	Somewhat Negative	3.0
7	5	Quite Negative	7.3

Another question asked for a comparison of the workload per week between conventional and *CAPA* homework. Figure 7 shows the additional hours worked per week for a *CAPA* homework compared to the non-*CAPA* class. The figure displays the correlation with the approval rating of *CAPA* ("How do you rate *CAPA* as a learning tool?") by the students. The average values

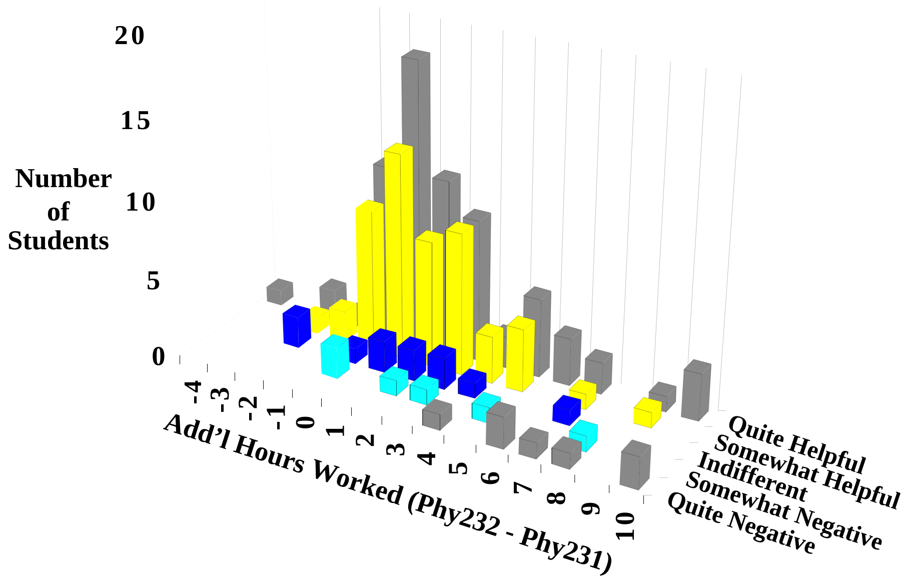

Figure 7. Two-dimensional display of the additional hours worked in the *CAPA* class (PHY232) compared to the traditionally taught class (PHY231) as a function of approval rating of *CAPA* by the students.

for the extra work for the five groups is listed in Table 1. One of the most interesting aspect of the figure is the fact that a $\sim$ 10% of students who have to work substantially harder ($\geq$ 5 hours per week more) still think that *CAPA* is a great learning tool (quite helpful). On the other side all seven students who rated *CAPA* quite negative appeared to require an excessive amount of work to solve the problems.

One major reason for the positive student feedback is the trust of the students in the computer. The coding of the *CAPA* homework sets were essentially error free. Even a few errors in the *CAPA* solutions would have destroyed the confidence of the students. Out of the over 200 problems of homework and midterms only one problem was initially coded incorrectly. However, it was quickly corrected on-line thanks to one of the brightest students in the class who solved the set early and contacted the instructor because he could not understand what he was doing wrong in this particular problem. The students tried extremely hard to get all the problems. For example there were students who worked until 3am and solved all problems except one, and then logged in again at 7:30am and finally succeeded on that last problem and got the "CORRECT" from the computer. The students continued to work until they solved the problems because they were convinced that the *CAPA* answers were correct.

6. Conclusions

Using *CAPA* has proven to be an effective teaching tool which is very much appreciated by the students. The very positive feedback from the first application of *CAPA* in non-science classes does not seem to be just a "novelty" effect. The much more computer literate science majors (a growing number of students used their computer at home and a modem to connect to the system) also overwhelmingly approved of the system. Currently *CAPA* is being used or installed in several classes at MSU (physics, chemistry, calculus). It is also starting to be used in physics/chemistry classes at other institutions and early reports appear to confirm our observations as reported above [12].

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