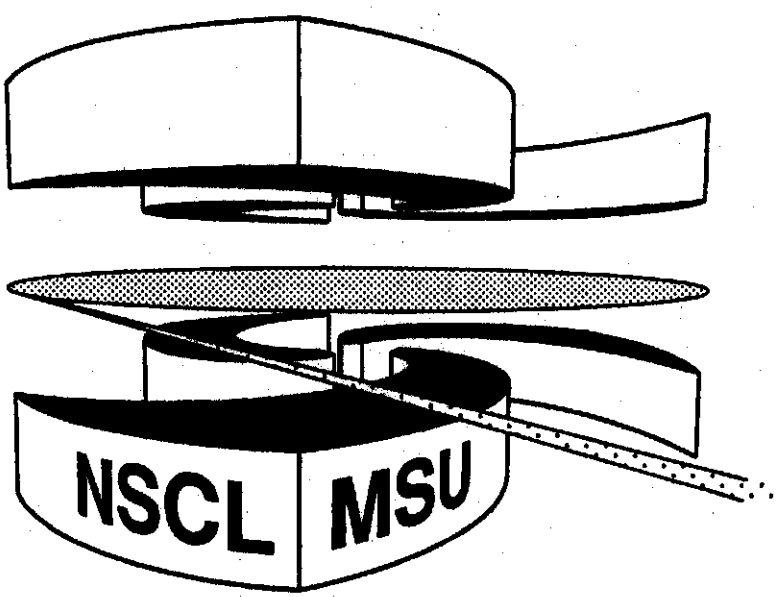
Michigan State University

National Superconducting Cyclotron Laboratory

CAPA SYSTEM UPDATE

E. KASHY



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CAPA[1] System Update

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[1] CAPA is a networked, integrated Computer Assisted Personalized Assignment System.

Introduction

The networked Computer-Assisted Personalized Assignment system (*CAPA*) developed at Michigan State University (MSU) was first used in a small physics class in Fall '92. It has now been employed by over 1200 students for assignments in introductory physics, chemistry, and mathematics. At present the system requires an Intel-486 Workstation running the NeXTstep operating system. A number of schools have expressed interest in *CAPA*, and some implemention of the system outside MSU is taking place.

The student responses have been highly positive, and the preliminary evidence indicates that using *CAPA* has stimulated and motivated the students in these classes to work more diligently. Its implementation appears to be a significant (and cost effective) tool for achieving quality education in the sciences. The system fosters several key ingredients of successful education and does not intrude in the instructor's course design, content, or goals. Two papers have been written describing the system and the initial experience with its use, one has appeared in the American Journal of Physics [Ka93] and the second will appear soon in the Journal of Chemical Education [Mo94].

The *CAPA* system has been developed with the strong support of MSU. Faculty and graduate students from several disciplines have collaborated in its design and implementation. Students, both graduate and undergraduate, have helped with problem coding. It is now a thoroughly tested system and has worked remarkably well.

There are many interesting and effective tutorials and simulations created to reinforce classroom concepts. In laboratories, computers have been integrated in the experiments and in the data acquisition and analysis [La91] Such applications are usually focussed on specific topics. They often include quite sophisticated graphics and run on computers with specific hardware options. Thus, large laboratories of such machines have to be provided. The *CAPA* system does not diminish the need for such simulations and tutorials because it represents a very different use of computers. It does not involve extensive on-line interaction by students. It has several features in common with other computerized assignment systems [Me93, Ch93, Le91], but is a significant step in functionality and student acceptance. It is not specific to a particular topic or curriculum. The hardware requirements on the student

side were made as low as possible to reduce costs and guarantee easy access.

The CAPA system and the experience using it is described below. Evidence of its effectiveness in motivating students is then provided. Finally, the work plans to continue its development are outlined.

System Features and Discussion

The CAPA operation relies heavily on modern networked computer technology. Its success depends upon the instructors who must write (or select from previously encoded materials) relevant, interesting, and challenging questions with correct solutions. We have completed the second year of using the system at MSU, and now have more experience and information that is remarkably consistent with initial published results [Ka93, Mo94]. The discussion below of its principal features reflects this added experience.

** The system allows the instructor to produce, for each student, a printed individualized assignment which differs from all others. A student's answers are unique while the concepts and principles which must be understood are the same for all students. All the information required to do the work, particularly figures and diagrams, is included on each printed assignment. Because the assignments are unique, students are encouraged to study together [Tr92], to discuss and understand the concepts, and yet each must still do his/her own work to obtain correct answers. To learn and achieve the goals, each student should do some independent work, and this process is fostered when students who study together solve similar but not identical problems.

** On-line participation by students is optional, a feature which probably contributes to its popularity. A student may choose to enter answers directly via any networked terminal or computer, or may instead hand in written solutions on the due date to be graded in the traditional manner. The system readily provides the grader with each student's unique answers to facilitate grading.

** Multiple attempts to solve problems on-line are allowed without penalty, with full credit given for correct solutions entered before the due date. This 'No penalty' feature encourages the students to understand and to correctly solve all the problems. It eliminates the judging and ranking of students while they are learning. The system does however record the pattern of data entry, including errors, thus providing valuable information to the instructor.

** Students can be given some on-line guidance in the form of hints. These allow assignment of more challenging questions and problems. Hints can be tailored to the class, and allow the instructor to 'instruct' a little outside of class time or office hours.

** An instructor may include explanations, which can be read by the students after the due date of an assignment when all the computer-calculated answers have become available. This feature was requested by students and is being used extensively in chemistry.

** When using the network, students get immediate, accurate feedback on problem solutions while they are working on the problems. In the traditional method of hand grading, feedback is usually not given for several days; meanwhile the class has moved on to new subject matter. Students profit from timely feedback, and with CAPA they are informed promptly and in no uncertain terms whether they have understood the concepts and were able to apply them correctly. (An anonymous student's comment: *'I think it is a good system. It makes me feel kind of poorly though because I think I understand the concepts before I do the homework but CAPA proves me wrong most of the time.'* makes the point.) Every student has the opportunity to achieve the goals which the assignments represent. For the better prepared and perhaps more gifted student, this may require a relatively small effort. For students whose earlier preparation has some significant shortcomings, the opportunity to achieve the goals by diligent work is provided. They can also get individual help at office hours throughout the week.

** Because summaries of success and failure on questions and problems are available on-line, the instructor can address difficulties before the due date of an assignment. The instructor can change or elaborate the 'hints' associated with particular questions, or address apparent difficulties at the next class meeting. The system also provides information on the progress and performance of a particular student so that needed action can be taken early.

** CAPA promptly rewards correct work. The students' reactions showing excitement and pleasure when they see '**Correct, Computer gets.....**' are fun to observe. They can see their grades build toward 100% as more correct answers are entered, and it is remarkable how many refuse to stop at 15 out of 16, or 16 out of 17. They appear to be driven to get that last point. Login records confirm that this is a widespread effect.

** The system has many options for numerical and qualitative Multiple Choice problem

styles. Examples are presented in the figure on page 5, combined in the format of actual assignments at MSU. The high definition of laser printing of postscript graphic files is well suited for problems with graphical methods of solution (e.g., #7 on page 5).

Most numerical problems have variables that are randomly distributed. Actual data is often used to give realistic results (e.g., in #5 (page 5), the energy and the thickness are picked randomly, but the fraction of neutrons not interacting is based on experimental data). The Select N-correct out of M-choices questions are especially useful for problems in which several causes can lead to an observed phenomenon (e.g., #3 on page 5) and in addressing previously held misconceptions (e.g., #4). CAPA makes it easy to word statements in several ways and to randomize their order; this forces collaborating students to communicate the correct information thus reinforcing learning. Some assignments have also included essay and/or derivation questions. For a derivation, some feedback on the correctness can be given (i.e. #11, with #12 giving on-line feedback). Such answers are turned in (or e-mailed) to be graded, and students can see the number of points gained during their next login.

** CAPA relies on the internet but only requires a VT100 terminal or emulator. Only the standard 128 ASCII characters are used to prompt the student; graphs, scales, tables, etc.. are not recreated as we expect the students to work from their printed assignment. Many campuses are now equipped with numerous, easily accessible personal computers with terminal emulation software. Over 34 different campus locations have been used by students at MSU. We also see an increasing numbers of students who use their own modem-equipped PCs to login over phone lines, a trend we expect will continue.

** The very high level of student participation via the network virtually eliminates the potentially tedious grading of individual assignments.

** CAPA has helped to reduce the impersonal nature of instruction in large college classes: At MSU, we have eliminated the recitation sections in the non-calculus introductory physics sequence where CAPA is used, a popular change with students. Instead, in Spring '94, 28 office hours were scheduled each week. This increase in office hours for the professors and TA's is compensated by the considerably reduced grading load. By interacting more with the instructor and the teaching assistants, students receive the individual attention needed to address their particular difficulties.

Student, John Q. **section 6**

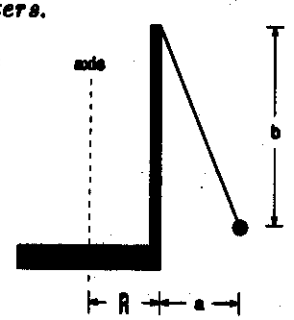
Sample Problems Prepared with CAPA

phy231f4 – MSU – Fall 1994 Assignment Number 7. Due 12/31/94 Give 3 digits for numerical answers. PIN is 1439

1. Test your skill at using your calculator by checking that $(1.50)^2$ equals 2.25 and that $(1.50)^3$ equals 3.38. Now, find the value of $(1.50)^{2.9}$

2. A small sphere of m = 0.11 *kg* is suspended by a light string from a vertical post mounted at the edge of a merry-go-round of radius R= 0.410 *meters*.

The equilibrium position of the sphere is shown in the figure, with 'a' = 0.410 *meters* and 'b' = 0.820 *meters*. The axis of rotation is indicated by the dashed line. Calculate the angular velocity of the merry-go-round in *radians/sec*.



3. John is listening to a horn. He knows the frequency of the horn is 300 Hz when both he and the horn are at rest. If he hears a pitch of 270 Hz, there are clearly several possibilities. Choose all possible options (e.g. ACE, B, ...).

A) Both can be moving and have different speeds.
B) Both can be moving, in opposite directions.
C) John is moving away from the horn at rest.
D) The distance between John and the horn is decreasing with time.
E) Both cannot be moving in the same direction.
F) Both can be moving and have the same speed.

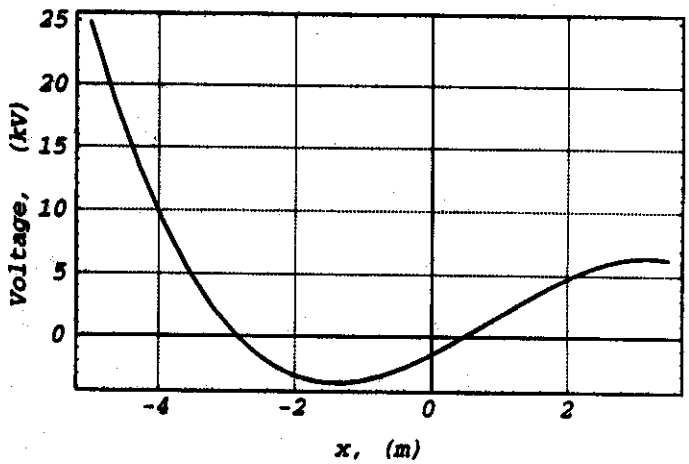
4. Identify all the correct statements (i.e., A, CD, ADFG,..).

A) Seasons in the northern hemisphere are due to the variation of the earth's distance from the sun.
B) The earth is nearer the sun in December than in June.
C) When it is summer in Iceland it is also summer in Chile
D) More than 99 percent of the energy heating the earth comes from the sun.
E) Winters are colder than summers because of clouds in the sky.
F) The tilt of the axis of rotation with respect to the earth's orbital plane causes the seasons.
G) The shorter path of sunlight through air explains why summers are hotter than winters.

5. Neutral particles interact by random collisions in matter. When a beam of 61 *MeV* neutrons goes through a concrete slab 18 *cm* thick, about 43.6 per cent of the neutrons will not interact, and thus keep on going. What percentage of the neutrons would not interact if the concrete slab were made 36 *cm* thick?

6. How many *cm* thick would the concrete need to be so that 18 per cent of the neutrons are transmitted?

7. The electric potential along the x-axis (in *kilovolts*) is plotted versus the value of x, (in *meters*). Evaluate the x-component of the electrical force (in *Newtons*)on a charge of 4.50μC located on the x-axis at x = -2.4 *m*.

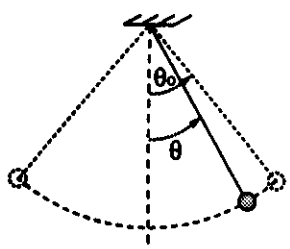


8. A power plant burns coal as its fuel. It generates 640 *megawatts* of electrical power while discharging 960 *megawatts* as waste heat. What is the efficiency of the plant for producing electricity? (give as percent)

9. Calculate the total electrical energy generated by the plant during a 30 day period. Assume its electrical power output is constant during that time. Answer in *joules*.

10. During the 30 days, how much mass is converted into energy? Give answer in *kilograms*.

11. The diagram shows a simple pendulum consisting of a mass M suspended by a thin string. Using first principles, i.e., Newtons's second law and acceleration for circular motion, derive an expression for the angle θ at which the magnitude of the tension is Mg. Hand in your derivation to the instructor.



12. If the pendulum is released from rest at θ_0 = 64.7 *degrees*, evaluate the (+) angle θ (in *degrees*) at which the magnitude of the tension is Mg.

13. Ethanol is a very popular organic liquid; it has a molecular formula of C_2H_5OH, a molecular weight of 46.07 g/mol, and a density of 0.7893 g/cm^3. Its melting point is -117.3°C and normal boiling point is 78.5°C . The heat of fusion is 5.02 J/mole and the heat of vaporization is 39.3 kJ/mole. Calculate the vapor pressure in atmospheres of (pure) ethanol at a temperature of 60.0°C.

14. Evaluate the definite integral $\int_{1.90}^{2.90} (x^2 + 4x)dx$

** CAPA can insures that Teaching Assistants (who are generally required to do the assignments ahead of the class, and to login their answers) are well prepared before they interact with students. The TA's thus play an additional important role, checking that enough information is provided in each problem and that computer solutions are correct.

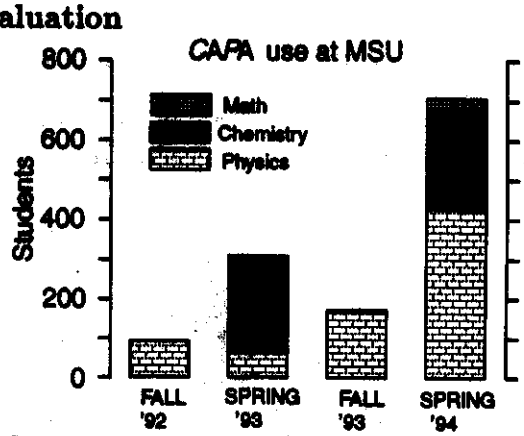
** The "Computer" as arbiter of what is Correct or Incorrect changes the role of the instructor from judge to that of a helpful, friendly mentor.

** It has promoted increased and valuable dialog about teaching among instructors (and between instructors and students). Together with the on-line evidence that students are working, it has added interest and enjoyment to teaching.

The CAPA system has also been used to generate mid-term examinations. Because the exams are individualized, students can be seated in close proximity without providing any temptation or opportunity to 'cheat', an important concern for many students and instructors. An answer form is used to record answers obtained during the examination period. Students keep their questions, and afterwards may login to check their performance. They are also given the opportunity to re-work missed problems (within 3 to 5 days) with the inducement of partial credit for corrected problems. Almost all students avail themselves of this opportunity, with the great majority correcting all mistakes. This has generated many student-hours of concentrated effort to learn the material on the exam which might otherwise not have taken place!

Use and Evaluation

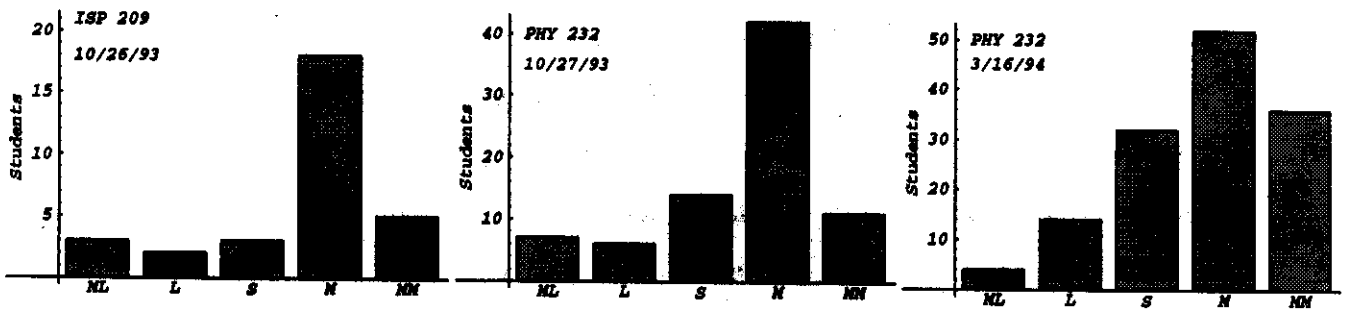
The use of CAPA by students these past 2 years is displayed in the figure on the right. It is expected that next year there will be as many as three times more students using the system in introductory physics, chemistry and mathematics.



An important element of effective education is to 'engage' students in the learning process. Using CAPA appears to contribute to that engagement as they are more personally involved and responsible in the learning process [Au94]. In the many surveys of students

in different classes, students have responded with highly consistent opinions of the CAPA system. Students were asked to compare the time they spent working their assignments using CAPA as opposed to TA graded assignments. These qualitative responses are plotted below for three recent classes. The figures indicate that on average more time is spent, but with an increase that is not excessive.

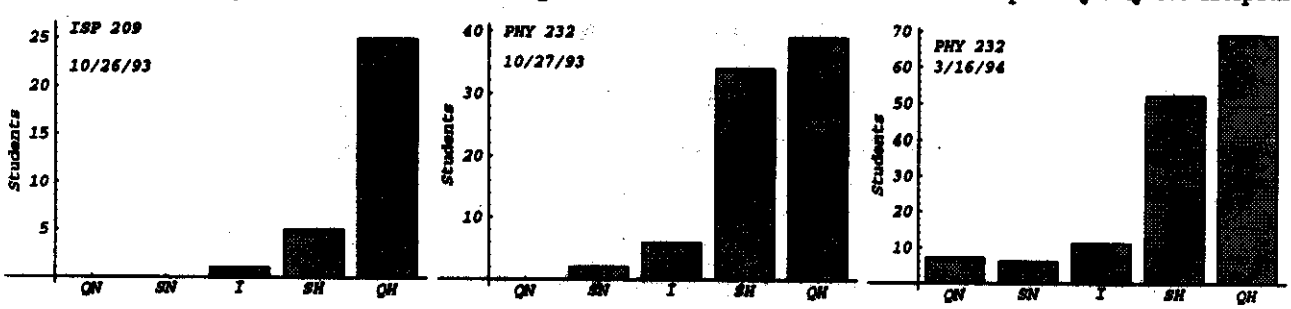
Amount of Time spent using CAPA vs TA-Graded Assignments
ML=Much Less. L=Less S=Same M=More MM=Much More



In the most recent Physics class (Phy232), students were also asked to estimate the average time they were spending on the weekly assignments, and the amount of time they had spent in the preceding course (Phy231, the previous semester of non-calculus physics where CAPA was not used). The average weekly time was 5.7 hours for Phy232 (using CAPA) compared to 3.3 hours for Phy231, a significant and important increase [Th94].

In spite of the increased time spent the system is rated highly by students as an effective tool for learning and understanding. This is shown below in the responses from the same classes evaluating the learning effectiveness.

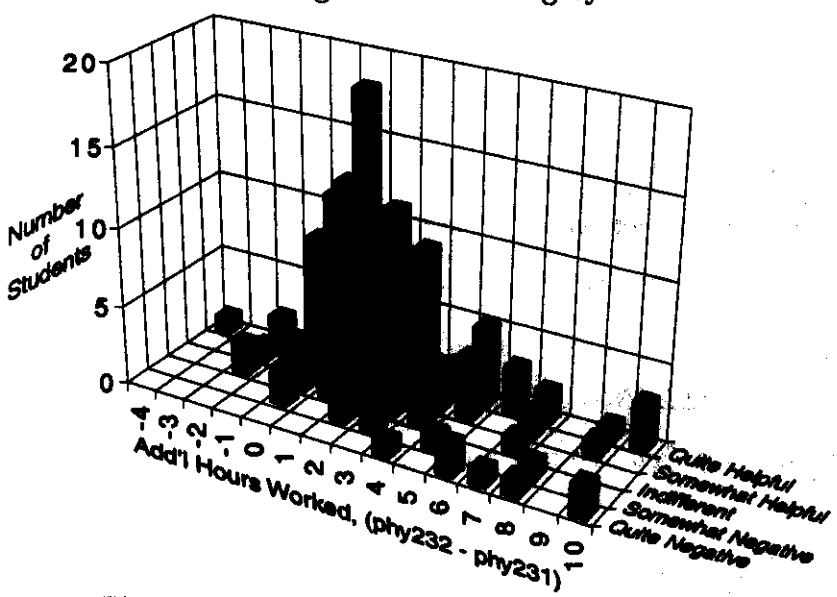
Evaluation of CAPA as a tool for learning and understanding:
QN:Quite Negative SN:Somewhat Negative I:Indifferent SH:Somewhat Helpful QH:Quite Helpful



Do these positive responses reflect a 'Happy Coefficient' associated with trying new things? We can't tell since only a few students have used the system in more than one

class. The often made comment *'I wish more profs would use it'*, or the recent e-mail *'Dr Morrissey, ... Dr. Tsai gave me your name to contact as to which Chem 141 sections are using the CAPA system this fall. I feel the CAPA system has greatly helped me with Calculus and I hope it can do the same for me in Chemistry. Thank you.'* indicate it is more than a "new thing" interest.

We have not had any 'quite negative' responses among the 270 students enrolled in ISP209 physics (a course for non-science majors). In classes for science majors, in both physics and chemistry these have occurred in about 4% of the responses and is of some concern. What is the cause of their reaction? A possible reason emerges when the evaluation response are correlated to the response about the additional time spent. That correlation is shown in the figure below, and the corresponding average additional time spent when using CAPA is tabulated on the right for each category.



PHY232, 3/16/1994[a]

# of students	Assessment of CAPA	Add'l Hours
69	Q H	2.4
51	S H	2.0
11	I	1.7
6	S N	3.0
7	Q N	7.3

[a] Class taught by M. Thoennessen and M. Harrison [Th94].

The few students who judged the system as 'quite negative' indicated that they were spending 7.3 hours more hours on their weekly Phy232 assigments than they had for Phy231 (on average)! They are clearly having a difficult time with the course. The table above also shows that much smaller increases are reported by the rest of the class. We note there were actually more students with a very large increase in work time who judged the system favorably.

To what degree are students benefiting? One of the tasks planned is to design and implement studies which will assess CAPA's impact on learning and understanding and identify

the different factors which play a role in motivating students. For now, we let the students speak for themselves: We have collected numerous anonymous comments, most of which are like '*It is an excellent system. It really helped me a lot.*' or '*I love it. This is so much better than recitation.*', or '*A great idea...* ' or the rare '*Get rid of it!*'. There are, however, also comments which identify a specific reason, and some of those listed below.

- *'The hints are extremely helpful...'*

- *'..if you don't understand a problem the first time, you are able to try again and most of the time understand it after you think about the problem again.'*

- *'..is a much fairer and easier way of grading homework than TA's. CAPA allows immediate answers to problems and students don't have to wait for several days for answers from TA's'*

- *'Using CAPA for homework and especially for the exam corrections is absolutely great. I have learned more than I probably would have without the computer system because I tried problems again when I first got them wrong the first time and therefore was forced to think about them one more time.... '*

- *'..It allows a student an opportunity to get 100% on something and makes them totally responsible for it. Plus, the personalized theory is good because we can work together and see the crux of the problem but in the end are responsible for our own destinies. Good idea!'*

- *'It can be somewhat frustrating trying to get the correct answer, but that tends to made me want to get the answer–it becomes a CHALLENGE.'*

- *'I spent more time because I knew what I got wrong, and could try again. I'm not happy unless I get a perfect score!'*

- *'I like being able to use it at my convenience.'*

- *'I have enjoyed the usage on the computer. I like knowing immediately whether I am right or not. I feel I'm learning more this way.'*

- *'...The instant feedback keeps the problems relevant, and I work harder to get a perfect score. If I had to wait a week to know what I got wrong I would have little interest in redoing problems...'*

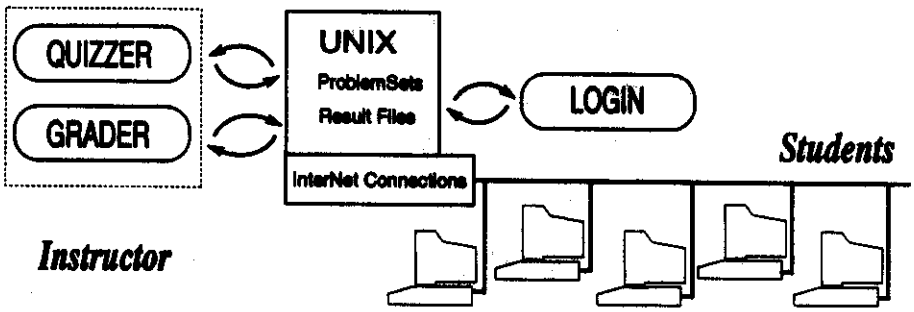
- *'.. It is nearly impossible to get a correct answer by guessing but because the system give many opportunities for getting the correct answer, it eliminates silly errors and rewards students for really understanding a question..*

- *'I think the reason CAPA takes longer than last years TA graded assignments is because I keep trying the problems until I get them all right. I really understand the homework by the time I'm done, so the system is definitely much better!*
- *'..I spend more time doing homework and I get much better information at the office hours than I ever got out of recitation.'*
- *'.. Also, the fact that the questions have different numbers is nice because it does cut down on blatant cheating.'*
- *'..It motivates yo to do the homework, because you know if you are getting the answers right or wrong. It is very discouraging when you think you are doing a problem right, then to find out it is wrong.'*
- *'..Forces you to keep up with the class work.'*

Finally, one section (25 students) of a large introductory Calculus class used CAPA for assignments this semester. Prof. C. Tsai of the MSU mathematics department reports a $\sim$ 20% increase in the weekly quiz grades compared to grades on similar quizzes in the section he had taught the previous year.

Outline of Planned Work.

1.) We plan to modify the software to make the CAPA system more accessible to a larger number of instructors. A schematic block diagram of the CAPA system is shown below.



The three software components are indicated by boxes with rounded corners and hardware with the square corners. The heart of the system is a Unix-based workstation connected to the InterNet that can support many simultaneous connections. This central machine also maintains the files containing the problem sets and the student records. The LOGIN code, automatically run to service each student connection, is written in 'C' and uses the normal Unix file structure. On the other hand, the instructor uses the QUIZZER code to create and maintain the problem set files and the GRADER code to handle the student grades and reports. The present codes used by the instructor require the NeXTstep operating system. Thus far, each instructor has run the entire CAPA system in a single workstation as the NeXTstep operating system is Unix-based and can support many remote users (n≈250). We have run the CAPA system on NeXT computers (no longer manufactured) and on Intel-486 based PC's.

We plan to make the CAPA system a distributed software system that will be more flexible and allow other instructors to use other hardware/operating systems to manage their files. The heart of the system will remain a Unix-based workstation, connected to the InterNet, that can service large numbers of students (n≈2500) and can export the CAPA files with the Network File System software (NFS). In the first stage, we will split the system into a central student-server machine and remote instructor's machine(s) running NeXTstep. Then we will port the GRADER and QUIZZER codes to Macintosh computers that will use the NFS-files on the student-server. Depending on the success of this project, we will consider porting the instructors codes to other operating systems, such as X-windows on large workstations,

or Microsoft Windows on IBM-pc machines. We will also be considering various means to protect the integrity of the information we collect and means to minimize the effects of hardware failures such as a disk crash.

2.) We will accelerate the development and coding of problems for introductory physics classes, both for non-calculus and calculus based sequences. This is a major, time consuming task, as problems have to be carefully reviewed for ambiguity, and the solutions coded must be essentially error free. It is very important to maintain a very small error rate i.e., less than 1%, as incorrect "computer" answers could waste students' time and would shake their trust in the system. (Some coding errors are bound to occur; they can usually be corrected on-line, or else a message can be promptly posted on the login screen to "Disregard Problem xx"). The problems improve with time as suggestions from instructors and students are implemented. These problems will be placed into a library whose structure is yet to be finalized although much work on possible organization of materials has been done.

We plan to collect well-tested questions and problems classified by subject, topic, type and difficulty level, from which assignment sets and mid-term exams can easily be assembled. Materials would be freely available for use by any interested instructor using the system; users would however be expected to contribute some materials to such a library. Protection of intellectual property could be accomplished for contributors of original problems by including in comment lines the authorship, the e-mail address of the originator, and a 'no unauthorized commercial use' statement within the code. Having the e-mail address would promote communication among intructors to resolve ambiguities, correct errors, or suggest improvements for problems in the library.

While a very large manpower effort has already gone into the system software development, a far greater effort has gone into the writing and coding of science questions and problems and in generating the associated graphics. Even more work is required. We think that well designed questions are the most important aspect for making the system effective in achieving the educational goals. Another aspect of the work we will be doing during the next year will be to improve and update the CAPA user manual [Ka94] as the system evolves and difficulties users experience are identified.

3.) We will design and carry out studies to assess the educational effectiveness of using

CAPA. Several instructors at MSU, not involved in the design and development of CAPA, have agreed to provide feedback on their experience with using the system. Some instructors at other institutions (Hope College, U of Ohio, ...) who are currently using CAPA or who plan to use it in the Fall '94 have also agreed to provide feedback on using the system and to facilitate interviews with their students.

In conclusion, the CAPA system[2] has now been used in several classes of physics, in two classes of chemistry, and one in one math section[3]. It has received remarkable approval from students, and motivated them to work diligently. Based on this experience, we are encouraged to continue development and assessment projects.

[2]The CAPA system software is copyrighted ©by the Michigan State University Board of Trustees. It is available to other institutions through the Office of Computing and Technology.

[3]CAPA has also been used in summer 1993 MSU sponsored pilot project which brought to the campus 4 school teachers for two weeks and 13 students during the second week, selected from groups under represented in science. They participated in basic nuclear physics experiments and in seminars with researchers, and viewed several demonstrations in related physics topics. Three problem sets (a total of 35-problems) used the CAPA system to reinforce their understanding. Its use helped to lower the level of apprehension of the teachers faced with the task of having to solve problems, allowing them to do so in a friendly, non-judgemental environment.

References

[Au94] Ann Austin, *Teaching for Understanding: Building on What Students Bring in the Classroom* Lilly Fellows/Faculty Seminar Series, MSU, 3/17/94. The discussion of various means of engaging student indicated that some of the CAPA features promote that process. Assessing the degree of engagement is however a difficult task. One thing we do know: the instructors are definitley engaged!

[Ch93] C.B. Chiu and C.F. Moore, *Centralized Computer System for Engineering Physics*, Manual, U of Texas at Austin. The UT and CAPA systems have several features in common, particularly those which address the logistics of processing assignments and exams for a large number of students. They differ in implementation, and to some degree, in philosophy. In the UT scheme, feedback to the instructor comes after the due date. For the students, the multiple choice format of the answers provides guidance and later posted grades provide feedback. With CAPA, feedback to the instructor (and students) is available on-line. Biggest technical differences: CAPA is a more integrated system, involves less paper (remote login of answers vs bubble sheet MC format), and has fewer individuals involved with the instructor responsible for and in control of every aspect outside of Campus Networking.

[Ka93] CAPA, *An Integrated Computer Assisted Personalized Assignment System*, E. Kashy, B.M. Sherrill, Y. Tsai, D. Thaler, D. Weinshank, M. Engelmann, and D.J. Morrissey, American Journal of Physics **61**, (12)1993, 1124-1130.

[Ka94] CAPA - *System Description and User's Manual*, E. Kashy, D.J. Morrissey, and Y. Tsai, MSUCL-925, January 1994.

[La91] P.W. Laws *Calculus Based Physics without Lectures*, Physics Today, **44**, No. 12,(1991)24. The use of microcomputer-based laboratory tools and of computer simulations and visualizations in the teaching of Physics is discussed and several references to such work cited. An appreciation for the very large number of specialized tutorial, simulation and visualization computer modules in chemistry can be obtained by scanning specialized publications such as the Journal of Chemical Education: Software, edited by J.W. Moore and J.L. Holmes, or the Computer Series, edited by J.P. Birk and the Computer Bulletin Board, edited by R.H. Batt, in the Journal of Chemical Education.

[Le91] R.A. Lewis, B.M. Harper and M. Wilson, *Computer Assignments and Problems Classes for Physics Students*, Computers Educ., Vol. 16, No. 4 (1991)349-362. We thank Dr. Lewis for bring this work to our attention. The system described (RALPH) shares many features with CAPA but also differs in many ways. It is quite similar to the U of Texas system alluded to in reference Ch93 above.

[Me93] S. Mellema, C.F. Niederriter and H.B. Thompson, *A Computer-based Homework System with Individual Problem Solving and Instuctor Diagnostics* ('Prob'), Bull. Am. Phys. Soc., **38**, (1993)1004. The CAPA system differs in philosophy from the 'Prob' system and has more features, the optional aspect, qualitative questions with 'N' correct choices out of 'M', graphics variations between assignments, correlated data sets, etc.., and is substantially different in its implementation. The two systems are similar for formula type problems. Both CAPA and 'Prob' are networked, contain the variation of parameters in numerical problems, and give instant feedback to the students. With CAPA, a student does not have to go to a computer to get the information required to do an assignment; it is all given to each student on the personalized assignment sheet. There is also no penalty assessed based on the number of tries needed to get a correct answer. The good performance seen obtained with both systems is encouraging.

[Mo94] *Using Computer-Assisted Personalized Assignments in Freshman Chemistry*, D.J. Morrissey, E. Kashy, and Y. Tsai, Journal of Chemical Education, Accepted for publication.

[Th94] Data from M. Thoennessen and M. Harrison, private communication (MSU).

[Tr92] U. Treisman, *Studying Students Studying Calculus*, The College Mathematics Journal, **23**, (1992)362.Numerous studies have shown the importance of collaboration among students in enhancing the learning process. The well known work of Uri Treisman at Berkeley has been emulated at numerous other institutions (often referred to as MATH-EXCEL program).

Multiple Choice Questions in CAPA.

An example of an *N*-correct out of *M*-choices question which is not science-based but might be appropriate for an American History class studying the Civil War is shown below.

> Which of the following states joined the confederacy late, i.e., **after** the firing at Fort Sumter (sometimes spelled Sumpter) on April 12, 1861? Give ALL correct answers, ie, A, C, AE, ABCD, etc.
>
> A) Virginia C) South Carolina E) North Carolina G) Tennessee
> B) Florida D) Arkansas F) Texas

This format with scrambled answers, several of which are correct, is very useful since in many physical situations there are several possible explanations of an observed phenomenon.

Next we have an example of a science question. Since most people are qualitatively familiar with the Doppler effect for the pitch variation of sound, consider the following problem.

> 'John' is the listener/observer. He knows the frequency of a horn is 300 hertz (Hz) when both horn and observer are at rest. If, at another time, he hears a pitch of 330 Hz from the same horn, there are clearly several possible explanations. Given the following choices, select **all** correct possible options:
>
> A) John is moving towards the horn which is at rest.
> B) Both cannot be moving in the same direction.
> C) Both can be moving, in opposite directions.
> D) Both can be moving and have the same speed.
> E) Both can be moving and have different speeds.
> F) The distance between John and the horn is increasing with time.

It takes a reasonable amount of understanding of the Doppler effect to select the three (or is it four?) correct options. Since the order is randomized in different assignments, students cannot just tell each other which set of letters is 'correct', but must communicate the information and therefore reinforce the learning process. Furthermore, for half of the students, the pitch heard by 'John' will be 270 Hz., so for them, the correct choices are different. (See question 3 on page 5.) Finally, there can be several wordings of a particular statement so that the physics content is the same, thus requiring careful reading by students collaborating on assignments.

1. CAPA Publications/Reports:

CAPA- *An Integrated Computer Assisted Personalized Assignment System*, E. Kashy, B.M. Sherrill, Y. Tsai, D. Thaler, D. Weinshank, M. Engelmann, and D.J. Morrissey, (American Journal of Physics **61**,(12)1993, 1124-1130.).

Using Computer-Assisted Personalized Assignments in Freshman Chemistry, D.J. Morrissey, E. Kashy, and Y. Tsai, Journal of Chemical Education, Accepted for publication, September 1993.

CAPA - *System Description and User's Manual*, E. Kashy, D.J. Morrissey, and Y. Tsai, MSUCL-925, Michigan State University, January 1994.

CAPA - *System Update*, E. Kashy, D.J. Morrissey, and Y. Tsai, MSUCL-932, Michigan State University, May 1994 (This document)

2. CAPA System Software and Problem Set Codes:

The CAPA system software is distributed through the MSU office of computing and technology[4]

A user manual (See ref. above) describes the system in detail. Information on system software license can be obtained from the Office of Computing and Technology (Current fee is US $250 for one Host license, with a decreasing fee for additional hosts; a site license can also be negotiated).

Software of coded problem sets which have been used in physics classes may be obtained by writing to Professor E. Kashy, Department of Physics, Michigan State University, East Lansing, MI 48840. They are freely shared with other instructors using CAPA and willing to contribute to a CAPA problem and question library. Problems source codes must be protected from student access, and problems may not be commercially exploited by anyone other than the author. (See discussion on p 14)

3. System Hardware Requirements:

(a) a NeXTstation (several in use at MSU), or,

(b) the NeXTstep OS on an Intel 486 machine. (We have tested a Gateway 4DX2 - 66V, 32MB memory, with 1GB HD, and using a Viewsonic 17" monitor with an ATI Ultra Pro Graphic card with VESA bus and 2MB of VRAM, and an Ethernet card - SMC Elite 16)

With the default system limit of 32 simultaneous login, we have shown that either machine is suitable for a class of up to 300 students that have problem sets due on a single date.

[4]Office of Computing and Technology, 400 Computer Center, Michigan State University, East Lansing, MI 48824