Computer Assisted Mathematics Instruction

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Abstract: Aspects of a computer assisted model of instruction for lower level mathematics courses including college algebra, trigonometry and finite mathematics will be presented. The overall philosophy of this approach is that students learn best by working problems for themselves. The system enables students to have instant feedback on their progress. When a student either solves a problem incorrectly or is unable to solve a problem, the computer provides a tutorial to indicate the correct methods and solution. The computer then generates a similar problem for the student to solve using the same concepts. The student is required to complete correctly each type of problem prior to each examination. This has fostered confidence and leads to success for the student. High and uniform standards are maintained on computer graded exams. Compared with traditional courses, statistics indicate higher grades in the computer assisted model and perhaps more importantly, better success in subsequent courses. With the assistance of a $449,999 grant from the NSF, experiments with this model are taking place in five different colleges and universities.

The computer assisted instruction which we call the Interactive Modular Mathematics Education system (IMME) utilizes the computer to facilitate the kind of teaching that has traditionally proven successful, specifically, to encourage students to learn by doing mathematics. The teacher still lectures and holds discussions, the students still read the text, answer questions and do homework problems. Tests are still given and grades assigned. All of this still takes place within the confines of a regular semester.

There are some significant differences however. Most good teachers ask frequent questions of their classes to determine the level of understanding of the subject matter under discussion. Unfortunately, unless there are only one or two students in the class, not every student is asked about every topic. Furthermore, it isn't possible to keep asking alternate questions when students don't know the correct answers. These things are made possible using IMME. Each student answers an entire series of questions on a given section or module. If students demonstrate a sufficient understanding of the subject matter then they are allowed to begin doing homework problems. If not, another series of slightly different questions is provided. This continues until each student has established appropriate proficiency. We require at least 90% correct on one series of questions.

Once the students have demonstrated a sufficient understanding, they are allowed to do homework problems. These are fairly typical problems but, in light of the reform movements by the NCTM and AMATYC[1], the focus has been shifted from complicated symbol manipulation to mathematical literacy and understanding of concepts. Of course, students are assigned problems in a traditional class, but are frequently frustrated and lose confidence when unable to do problems correctly and make meaningful progress on their homework. Even the more talented students will have to wait days before learning whether their work is done correctly. Under the IMME system the student receives instant feedback on every problem regardless of the student's location or the time of day. A student who works a problem incorrectly or who doesn't know how to work the problem can instantly access assistance specific to the problem through the tutorial option on the disk. Furthermore, the student is always provided with another, different but similar problem to work for her or himself. This continues until each student has worked each problem type correctly, on their own, at least once, but as many times as the individual student feels is necessary to prepare for a test.

The student must be at least minimally prepared (i.e., has satisfactorily completed the proficiency questions and has worked every type of problem) before being permitted to take the examination. Obviously, this policy almost assures each student a passing grade. Specifically, in our College algebra, 83.9% of those students completing all the work in the appropriate time period earned a grade of C or better. The other side of this coin is that a hard-working student does not have to wait for the entire class to catch up. The test over a module is ready at any time and may be taken at any time after completion of the module and before any deadlines set by the instructor. Deadlines discourage procrastination and are set by the instructor for the various modules and the final examination.

The tests are timed and are generated uniquely for each student. They are made up of questions and problems similar to those in the modules. The tests are a typical mixture of multiple choice, true/false or yes/no, and open answer questions and problems. Partial and full credit is awarded in an absolutely uniform way for every student according to rigorous standards. Of course, all colleges and universities try to ensure uniform, high standards for all their classes but even with common tests or finals it can't be known that a grade of A in one class means the same thing as a grade of A in another. With IMME it is possible for this to be absolutely assured.

The system was initiated at the University of Arkansas for Beginning/Intermediate Algebra in the fall of 1998 using the text developed by the aurthors[2]. The success rate (A,B, or C) improved from 26% to 48%. Encouraged by these results, we decided to try to determine the effectiveness of this modular algebra system as compared to traditional instruction in College Algebra classes. We taught 32 sections of College Algebra using four different methods of instruction that semester. The four course types were traditional lecture, large lecture (100 students) with smaller recitation sections, the IMME method, the IMME method adapted to paper (at that time our computer facilities were very limited). Except for the large lecture format all classes were about 35 students per section. The students were essentially randomly distributed.

The results of the study contrasting the four course types according to probability of success (grade of C or better). Briefly, the study indicated that the interactive modular system, whether using computers or paper, gave students a significantly greater probability of success than did either of the lecture courses. The interactive modular system in the paper version proved overwhelmingly difficult to deliver; too much of the instructor's time was required for grading and duplicating varied new versions of problems. Overall success rates for students in modular algebra classes was 63% and in traditional classes was 42%. All final exams had 13 questions in common. For these 13 questions the average percentage of correct answers by modular students was 78% compared to 67% for the traditional students.

To further analyze the effectiveness of these techniques, we followed our students into subsequent courses. College Algebra at the University of Arkansas is a pre-requisite for Finite Mathematics and Survey of Calculus, courses required for graduation for most students not pursuing careers in science. In the two-course sequences of College Algebra to Finite or College Algebra to Survey of Calculus the success rate for modular algebra was 33% higher than that of traditional algebra students. At the time of the study both Finite Mathematics and Survey of Calculus were taught in a traditional manner.

In the Fall of 2000, we began instruction in Finite Mathematics using the IMME method. In our former mode of instruction, students were graded on nine homework assignments, ten quizzes, four-hour exams, and a final exam; all quizzes and exams were multiple choice. Test packets of old exams were available to students and final exam questions were essentially the same as those in the packets. For the years from 1997 to 2000 in the traditional course, 45% of the students earned a grade of C of better. In the fall of 2000 using the IMME methods, 56% earned a grade of C or better. Subsequent semesters have seen similar results.

We were initially concerned that students would be intimidated by needing to use computers. However, in our study noted above, student evaluations indicated they in fact rated the IMME courses higher than the traditional courses.

For the first time, during the Fall of 2001, we were able to teach the IMME method at the University of Arkansas for nearly all sections of Beginning/Intermediate algebra, College Algebra, and Finite Mathematics in classrooms equipped with computers funded by a grant from the NSF. Our initial observations indicate that computer equipped classrooms have enhanced the effectiveness of the program. At the same time, the NSF grant has permitted five other institutions in three states to experiment with initiation of the IMME method. The five institutions are are both public and private with diverse missions. We are presently collecting information on their first semester experience. Several other institutions not associated with the grant intend to implement IMME instruction as well.

The mechanics of the system are relatively simple. Almost any computers can be used, there are no unusual memory demands or special features. All of the necessary software for the instructors, directions and assistance are provided at no cost. The only cost involved is the purchasing of the appropriate textbook by the students. The textbooks are reasonably inexpensive and brief since much of the material usually included in a traditional book is included in the software in the IMME system. Since there are no special expenses, it has been easy for institutions to experiment with a small number of sections.

We view the following as the significant consequences of the IMME instruction. Requiring students to answer conceptual questions correctly teaches students to read mathematical material and pay attention to lectures. Students working problems for themselves (different but similar problems until they solve them with tutorial assistance always available), is effective and at the same time imbues students with an indispensable self-confidence in their ability. Not allowing students to take tests until they have completed the minimal requirements of study not only greatly increases the probability of success but makes students responsible for their own success or failure. Freeing teachers from the tedious and time consuming tasks of preparing and grading exams, grading homework, and extensive lecturing permits teachers to concentrate on meaningful mentoring of students. We find that teachers spend less than half of their class time in the traditional lecture mode.

Bibliography

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