

Algebra as a Laboratory Discipline: Implementation of Standards

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I. Introduction

According to the AMATYCCrossroads in Mathematics Standards in Introductory College Mathematics, "our ultimate goal is to improve mathematics education and encourage more students to study mathematics." NCTM and AMATYC have concluded that we must equip all of our students to think for themselves and to solve their own problems and those of society to the very best of their individual abilities. Two of the major weaknesses in post-secondary mathematics education identified in Crossroads – problem-solving and communication – were judged by the University of Arkansas to be a primary target for improvement.

Many college students are not prepared for college-level mathematics upon entering college and must obtain the knowledge necessary by reviewing basic mathematics skills. At the University of Arkansas we provide a basic algebra course in an attempt to prepare students for success in college mathematics courses. Unfortunately, the standard "chalk and talk" approach results in very little student learning and high failure rates. Student's manipulative skills are fair, but generally speaking, they don't have a clue as to what they've done.

II. Student Oriented Math Education

To implement the Standards, in particular, regarding development of problem solving and communication skills, such as verbal communication, and reading/writing comprehension, we decided to begin by restructuring our basic math course (Beginning/Intermediate Algebra). Some of the things we decided not to do were:

- 1) Not to change to a textbook which emphasized the use of calculators. This was rejected since it was felt that, while this alone could possibly enhance problem-solving, it was unlikely to enhance communication skills.
- 2) Not to provide a teacher oriented emphasis but to make student's activities be the target. Aside from sitting in class, the student's activities consisted of doing homework assignments and taking tests. By changing the nature of those two activities a direct and immediate change in student learning could take place.
- 3) Not to switch to a project oriented textbook, but to increase the multi-step written projects assigned as small group activities and to incorporate these activities into the algebra sequence.

Since the course syllabus drives our teachers as they cover the specified topics in a given course, it is well known that there is little time for anything but lecture and going over homework problems and giving tests. Homework is not typically graded effectively, largely due to the constraints of time and the mere fact that teachers have little interest in grading homework. In addition students attitude in general is to get the work done regardless of whether they understand what they are doing. So, how do we get our teachers to change? We don't. We build the desired learning skills into the homework assigned and tests given.

Giving homework assignments and tests on paper is impractical. By changing the nature of homework assignments and test design, we thought why not have students grade their own homework and receive immediate feedback. This then could raise the standards for homework assignments. If we could

implement this approach then we could even design tests that emphasize communication skills. With this in mind we designed homework and testing software to use random number generation to ensure that effectively every student had unique tests and homework assignments. Furthermore, the questions and problems on tests and homework would be at the same level of difficulty and in the same format for every student.

III. The Program

So, with the desire to establish some real standards for our students, we decided to provide homework and tests on computers outside of the classroom. Our pilot project was the basic algebra skills course. Approximately 1,500 students per year enroll in this program. Students do their homework on computers either in the Mathematics Resource and Tutoring Center (MRTC), on any campus network computer, or they can install the program on a computer where they live. We have designed homework which ask specific questions about a problem the student is working.

Some specific features of this newly established course structure are:

- 1) Students can work a homework problem as many times as they want. Each time they work a problem they get the same type of problem, but with different numbers.
- 2) If a student does not understand the homework problem there is a Guided Tour that takes the student through the problem step by step. However, the student is asked specific questions along the way to help in the understanding of the concepts.
- 3) Students get immediate feedback as to their results. Recorded on their student disk will be, a) how many times they attempted to solve a problem, b) how many times they solved the problem correctly, and how much time they spent on the homework assignment. Upon request, teachers are provided with a printout of their entire class homework results.
- 4) Testing is conducted in the MRTC, thus freeing up the classroom for the teacher to have more time to cover concepts and provide group projects as he/she desires.
- 5) The test has been designed to ask more questions, and provides the student with a full 60 minutes to complete the test.
- 6) If a student completes a test before 60 minutes has lapsed, he/she is asked if they want to review the test questions and change any answers. Once the student turns in the test (by clicking on the "Turn in Test" menu), the student is told, a) how many total points were on the test, b) how many points they earned, and c) what percentage score this represents. If a student is still working on a problem at the 60 minute point he/she is permitted to finish the problem before the score is determined and recorded on the student's disk.
- 7) Three tests are administered during the semester. The students can sign-up for a makeup test on the first test. The tests are given over a period of 4 or 5 days, the final exam (2 hours) is available during the entire final week. A class reader program records the test scores and results are provided to teachers.

The problems chosen for the test and homework software are almost identical with problems from the textbook and from previous tests given on paper. However, there is a subtle but very significant difference. On paper a problem is posed and the student writes down all attempts at solving it. Typically the grader looks at the students work and if any of the attempts are in the right direction some partial credit is given even if the correct answer is not there. For the same problem on the computer the student is asked a specific question and credit is only given for a correct answer. This requires the student to not only be able to solve the problem and get the correct answer but also to know the meaning of that answer. An example is a division problem of polynomials. It is amazing how many students can work such a problem

correctly and not be able to answer a question such as "What is the remainder?" or "What is the quotient". Fortunately, they can and do learn to answer the questions but it is frequently a brand new concept.

IV. Results

The software has been class tested in selected classes here at the University of Arkansas during the time it took to develop, refine, and improve it. Other schools such as Florida International University in Miami, Florida, Collin Community College in Plano, Texas and the University of Mississippi, Oxford, Mississippi have been using either the homework software or test software or both. Feeling that the software was sufficiently class tested we implemented the program in all seventeen sections of Beginning/Intermediate Algebra this semester. Thus, all students enrolled in this course have homework assignments and take all their tests on computers.

Data has been collected on several previous class performances, however, significant analysis will not be completed until this academic year has been completed. Currently, students are averaging about 60% on their homework and tests. We anticipate this will improve as we fine tune procedures. This semester, as additional warm-up for the first test, all students were required to complete at least 3 homework assignments on computers prior to taking the test. Also, on the first test due to the new format, we allowed for one repeat test. Despite some logistical difficulties with some students being late or forgetting their time everyone had the opportunity to be tested.

V. Plans

Having established this beginning/intermediate algebra program, all students are doing homework assignments and taking tests that all have the same grading standards, it is now possible to begin the process of upgrading uniformly individual problems and questions on tests and homework. Each time a student takes a test or does homework on the computer, the results are recorded on a computer disk. This is what will enable detailed ongoing analysis and modification of the questions and problems on each test or homework assignment resulting in a continually improving assessment tool. Perhaps more importantly the questions and problems that make up the homework assignments can also be improved on a continuing basis because new problems and questions can be added to or deleted from the system easily and because such changes can be guided by a solid factual basis of results, the improvements should be rapid and sure.

The beginning/intermediate algebra comprise only about 20% of our algebra students. In order to expand to provide the same improvements and uniformly higher standards for all of the algebra students will require considerably more resources than we presently have. Thus application for an NSF Grant is underway at this writing, to cover additional equipment and materials that will be required. A major portion of the revised College Algebra course will be to provide a number of group projects rather than spending time on rote learning of basic skills. College Algebra, as proposed, will become primarily functional analysis, because students should already know how to solve equations needed to interpret graphs.

VI. Conclusion

Providing a computerized program for homework assignments and testing has allowed us to raise standards. By moving homework and tests outside the classroom we provide teachers more time to interact with their students. Topics previously covered in the classroom that were not considered pertinent for preparation for College Algebra have been omitted. Thus the teacher is able to do more group work and collaborative learning projects. Based on earlier pilot projects we have learned what to do and what not to do to obtain reasonable results. The computer material provides us with some control of what is taught. Our desire is to see students master their basic mathematics skills so they can take college mathematics courses and be successful.

The benefits of this system to students, teachers, and society are only just now becoming clear. Here is a list of benefits that are already obvious.

Benefits to Teachers

1. More classroom time to teach instead of sitting while students take in-class exams.
2. More free time instead of grading homework or test.
3. The teacher can become a partner in the process of the student learning enough to make a good Grade. Teacher and student versus the computer.
4. More classroom time for group projects or individual writing projects since there is no longer a need to work homework problems that the students have missed.
5. Confidence that their students are being judged by the same standards as all the other students.

Benefits To Students

1. Fairer. Students all get different tests but all are at the same level of difficulty and are graded equally.
2. Students learn to read and understand questions and instructions that contain mathematical words and symbols.
3. Students have tutorial help immediately available on every problem even at home or work.
4. Students can have unlimited practice with randomly generated questions and problems.

Benefits to Society

1. Assurance that a student who receives a high grade has been held to high standards.