The Use of the TI-92 Calculator in Developmental Algebra for College Students

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In the highly technical world of today, there remain large numbers of students whose algebraic skills are inadequate. The dependency of growing numbers of courses, majors and careers on thorough mathematical understanding have caused mathematics departments across the country to play the role of gatekeeper. Students able to master the material presented in college algebra, precalculus and calculus are allowed through the gate and given access to majors in science, engineering, and other technical fields, while students whose algebraic deficiency prevents success in any of these courses are denied that access.

The problem of attracting women and minorities into the fields of science, mathematics and engineering has been documented for many years. Although many programs have attempted to encourage under-represented groups into these fields, the problem is far from resolved. Not only are there few women or minorities in advanced mathematics and science study nationwide, but there is also a growing number in these under-represented groups who are completely unprepared for collegiate mathematics at any level.

Although there are many students who have no difficulty with algebra in high school, the number of students who arrive on college campuses with serious deficiencies in their algebraic skills is definitely not shrinking. More and more colleges offer mathematics courses which avoid algebraic computations rather than trying to remediate the students whom they have enrolled. Unfortunately, algebraic competence is a necessary skill for introductory courses in many fields. Therefore, access to important career fields is denied to a group of students who may not understand the significance of their algebraic deficiencies until it is too late.

Developmental courses in algebra are offered at many community colleges and at other colleges with an emphasis on educating undergraduates. Unfortunately, one or two semesters of developmental algebra cannot make up for three to four years of practice with algebraic manipulations. Moreover, for the student who has failed to learn algebra despite repeated attempts during high school, the likelihood of a single course at the college level reversing that trend is small, especially if the techniques for teaching the course are not significantly different. At Columbia College, the number of students who have been able to successfully complete a general education mathematics course the semester following their initial enrollment in a traditional developmental mathematics class has been less than thirty (30) percent. Even when the completion of a developmental sequence enables a student to complete minimal collegiate mathematics requirements, it is seldom sufficient to enable the student to enter scientific or technical fields of study.

Ironically, the “algebra bottleneck” is allowed to exist in a world in which, for the mathematically proficient, the need for sophisticated algebraic dexterity has diminished significantly. Not only are there computer algebra systems which can perform symbolic manipulations with accuracy and speed beyond human capability, but also there are now handheld calculators which incorporate this capacity. A few campuses have recognized the potential that technology may have for alleviating the problem. Unfortunately, for students to whom algebra is an anathema, technology is useless. Unless a student is able to understand the underlying concepts, he will be unable to use the technology successfully. For example, a student must know what factoring means and why it is useful before the facility of a computer to factor algebraic expressions has meaning. Additionally, he must be able to interpret a problem and write an equation before any form of technology can solve that equation. Thus, while these technological advances do not automatically provide access for the mathematically weak, they do offer a new kind of hope for those institutions committed to providing this access.

Historically, mathematics teachers have equated symbolic manipulative skill with mathematical ability. However, there is a body of evidence that suggests that mathematical understanding is not dependent on symbolic proficiency [Nathan, 1997, Koedinger, 1997 and Hall, 1989]. By separating the concepts of algebra from the skills of symbolic manipulation, teachers can build on students’ intuitive knowledge and enhance their understanding without triggering the frustration developmental students often feel. With the advent of computer algebra systems, it is now possible to concentrate on understanding even with students whose symbolic skill level is deficient.

The Mathematics Department at Columbia College has piloted a program to revolutionize developmental mathematics at the college level by taking advantage of the new handheld computer algebra systems and the new information about the ways in which students might learn mathematics. The program, designed by our faculty, builds on work concerning student intuitive understanding about mathematics [Koedinger, 1994; Tabachnek, 1994] and on the role of manipulative devices in helping students to understand concepts [Kinard, 1996]. However, the program extends those ideas into a complete developmental algebra curriculum that is based on conceptual understanding not symbolic proficiency. Students who have mastered concepts learn the traditional algebraic algorithms, but then move quickly into using the TI-92 calculator to facilitate the symbolic manipulations. A sample of the curricular materials is contained in Appendix F. Our approach has been amazingly successful at our college.

In the fall of 1996, one class of developmental algebra students, selected at random from the three sections offered that semester, worked with the new four-pronged approach to learning algebra. Careful attention was paid to building on students’ intuitive understanding of mathematical principles; to using algebraic manipulatives to help students acquire an understanding of the underlying concepts; to developing traditional algebraic techniques out of this understanding ; and to employing the TI-92 calculator to facilitate computations.

The classes not selected to experiment with the new approach were used as a control group to evaluate the possible effects of the change in the curriculum. Students in both groups were given a mathematics attitude inventory [Sandman, 1980] at the beginning of the semester and at its conclusion. In addition, students in the subsequent course, intermediate algebra, the following semester were given the mathematics inventory at the end of the semester. Students who had taken the developmental course in the fall were also traced in the spring to determine the percentage who were able to complete the next course successfully. All of the data collected indicated that the new materials had an extremely positive effect on student attitude and performance. Actual statistical data follows.

Students are placed in developmental courses by a placement test which was designed by our faculty for use at the college. The test has been used for several years and has proven to be effective in determining the need for developmental work. Table 1 shows that although the mean placement score in the two groups was different, the difference was not significant ($p = .16 > .05$)

	Mean Raw Placement Score	N	Standard Deviation
Experimental	11.166	24	3.69
Control	9.977	44	4.24

Table 1
Comparison of Placement Scores in All Students in the Experiment

Students in both classes were given the same final exam. The difference between the mean final exam grade in the experimental group and the control group is significant with $p = .005$

	N	Mean Final Exam Grade	Standard Deviation
Experimental	24	81.9	12.31
Control	34	71.4	14.62

Table 2
Comparison of Final Exam Scores in All Students in the Experiment

The Mathematics Attitude Inventory was given to all developmental students during the first week of classes and again during the last week of classes. This inventory uses a 4 point scale to illicit student responses on 40 questions, with 4 indicating the most positive attitude. In this table, mean scores for the two groups are given with standard deviations in parentheses after the mean. The only difference that was not significant was the change within the control group from the beginning to the end of the semester. It is possible that the difference in attitudes between the control group and the experimental group at the beginning of the semester is an extension of the differences in ability indicated by Table 1 or it may reflect the anticipation within the experimental group about using the new calculators.

	Prior to Course	N	At the End of the course	N	p value
Experimental	2.74 (.31)	21	2.83 (.39)	19	.025
Control	2.42 (.37)	31	2.47 (.37)	19	.32(>.05)
p value	.025		.025		

Table 3
Mathematics Attitude Inventory for all Students in the Experiment

All developmental students are encouraged to take the standard general education course the semester following the developmental course. The students who participated in either group in the experiment were followed to determine the effect the experiment might have on their subsequent success. Students who made a C or better in the course were considered successful. (The results were so dramatic, that records from the previous year were also pulled to provide information about the differences between the teachers.)

	# in developmental algebra	# passing next course	percentage successful
Experimental (teacher A)	24	15	62.5%
Control (teacher B)	44	3	6.8%
Previous Year (teacher A)	21	6	28%
Previous Year (teacher B)	36	12	33%

Table 4
Comparison of Success Rates within One Semester

The Mathematics Attitude Inventory was also given to all sections of the standard general education course at the conclusion of the semester. Student responses were divided into three groups - those who took the experimental developmental course; those who had taken a regular section of the developmental course, either in the control group or in previous semesters; and those who did not take developmental course at all.

	Mean Attitude in Mathematics	N	Standard Deviation	p value
Students who took a regular developmental course	2.52	25	.33	
Students who never took a developmental course	2.79	14	.38	.05
Students who took the experimental course	2.94	15	.32	.05

Table 5
Mathematics Attitudes at the Conclusion of the Next Semester

Academic Year	Total number of Students Enrolled	Number who dropped before mid-semester
1993/94	118	13 (12%)
1994/95	101	16 (16%)
1995/96	82	8 (10%)
1996/97 traditional	71	5 (7%)
1996/97 new	50	0
1997	74	1

Table 6
History of Student Persistence in Math 001

Response category	Number out of 56 who included this category
The teacher	43%
The curriculum	29%
The calculator	29% (5% listed only this reason)
Level of support available	9%
My own maturity	5%
Less anxiety	4%
Note-taker	2%
Everything	2%
The chance to refresh memory	2%
More interesting	2%
No improvement	7%
Dislike calculator	4%

Table 7
Responses from current students to the prompt: Do you find that your attitude toward mathematics is more positive now than it has been? If so, why do you think this is true? The percents have been rounded and multiple answers were attributed to single responses so the total of the percentages is more than 100%

Our original goal was to improve attitudes without sacrificing success rates. We were astounded to realize the dramatic improvement in success rates in subsequent mathematics courses. Additionally, anecdotal evidence has convinced us that many of the students who took the experimental course now plan to enter fields of study that would have previously not been open to them. The rate of success of the students who took the experimental course encourages us to believe that this new approach to developmental studies had merit. Although it has not been tested on sufficient numbers of students or in sufficient circumstances to guarantee the transferability of the design, the preliminary information has encouraged us to enlarge our study. We are now using the technique on all sections of developmental algebra at the college.

The two most frequently asked questions about this experimental course from colleagues from other institutions have concerned the expense of the calculator and the choice of the TI-92. The TI-92 was the only hand-held calculator wich is capable of symbolic manipulations, although at this writing new symbolic calculators are expected to be available in the summer. It is that capability which allowed students to be successful. Clearly, the calculator will do many more things than our developmental students use, but our hope is that students who learn their algebra this way may indeed eventually be able to take advanced mathematics and engineering courses. In terms of expense, we have reached a compromise with our students. We provide the calculators in class and in our mathematics lab. Students are encouraged to buy their own, but are not required to do so.

We were so encouraged that we are now using the new approach in all of our developmental algebra courses. We have also continued to follow the progress of the original experimental group. Of the twenty-four students originally enrolled in the pilot course, seven have taken courses beyond the minimal mathematics requirement, and one is currently enrolled in calculus. It is noteworthy that none of the seven purchased a TI-92 calculator, so their continued success indicates a fundamental change in their mathematical proficiency, not just the benefit of the computer algebra system.

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