Effectiveness of Online Algebra Learning: Implications for Teacher Preparation

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Abstract: This study of an online algebra course looked at the overall effectiveness of the course and at the development, implementation, and evaluation of interactive tools for graphing linear equations. The first part of the study compared algebra achievement of virtual school students to that of public classroom-based students in the same state. The second part of the study focused on an interactive tool that was evaluated with virtual school algebra students. The performance of these students on the component was compared to the performance of students who did not use the intervention. The achievement of online algebra students was equivalent to that of students in face-to-face algebra courses, as was the performance of students learning in the online course with the interactive tools as compared to students not using the tools. The implications of the unique nature of the online algebra course for teacher preparation are discussed.

The quality of algebra curricula and instruction has received special attention in recent years when the mathematics test scores of students in the U.S. have been compared to scores of students in other countries, scores on state mathematics tests have been used to evaluate schools, and the need for qualified scientists and engineers has grown. As a gateway course to further education, algebra is a critical milestone in secondary education. Algebra is increasingly integrated into elementary school mathematics, and the majority of secondary level students take a stand-alone algebra course. States, districts, schools, and instructors need information about effective approaches to teaching algebra. Hundreds of online algebra courses are currently offered in North America annually, and their enrollment growth shows no signs of slowing. This paper describes the results of a study of the effectiveness of one online algebra course, and explores the preparation of teachers for online algebra courses.

Research has provided knowledge of effective algebra instruction in face-to-face classrooms (Beatty, 2005; McCoy, 2005; Gamoran & Hannigan, 2000; Carpenter, Franke & Levi, 2003). Over the last decade several studies have compared the mathematics achievement of secondary students in distance education programs to the achievement of their counterparts in traditional classrooms (Calderoni, 1998; Ryan, 1996; Yasin & Luberisse, 1998), and several states and provinces have released reports comparing mathematics performance of virtual charter school students with classroom-based students (Alaska, 2003; Colorado, 2003; Indiana, 2004; Minnesota, 2003; Schollie, 2001; Texas, 2003; Washington, 2003). While individual results have been mixed, taken together these studies and reports indicate that students in virtual school mathematics courses can be expected to perform at levels at least as high as students in traditional mathematics courses (Cavanaugh et al., 2004). However, each study and report has used a different measure of mathematics achievement, and none have looked specifically at algebra. In addition, the number of students in the past studies was as low as 7.

This study focused on the quality of an online algebra course, looking at the overall effectiveness of the course, and at the development, implementation, and evaluation of interactive tools for a particularly complex and abstract component of the course. The first part of the study was designed to learn how algebra achievement of virtual school students compares to that of public classroom-based students in the same state. The second part of the study focused on a specific component of the online algebra course that has been the most difficult for students, according to data collected on over 1300 students over the last four years at the virtual school where the study took place. An interactive tool was designed and developed, and it was implemented with a sample of virtual school algebra students to address the problematic component of the course, and the performance of these students on the component were compared to students who did not use the intervention.

The Setting for the Study

A state virtual school was selected as the setting for this study because of its long and successful history of offering high school courses to students online. The school was established by the state legislature in 1996 to offer education in cooperation with public schools, and now it operates as an independent nonprofit school serving students across the U.S. and internationally. The school educates thousands of students each year from a wide diversity of geographic locations, socioeconomic groups, and school backgrounds. Thus, the sample of students participating in the study was seen as representative of virtual school students nationwide.

Because each course offered by the school is developed by certified and qualified school staff, there was flexibility to adapt and evaluate course components. Courses are aligned with state and national standards, a factor that makes them similar to algebra courses offered in other settings. The algebra course is among the courses with the highest enrollment at the school, and the instructors of the course regularly collect data on students' performance in each module of the course as they work on continuous improvement of the course. Quality is a prime goal of the school, and it is enhanced through the use of frequent course reviews and outside evaluations. Therefore the school administrators and staff had a strong interest in acquiring knowledge via this study that would have the potential to improve the quality of the algebra course.

The Effectiveness of the Online Algebra Course

The algebra achievement of two groups of algebra students was measured using an established, reliable algebra exam. The groups were:

1. Students enrolled in online algebra courses developed by the Virtual School
2. Students enrolled in classroom-based algebra courses taught in state public schools

All students were taught by state certified mathematics teachers following the state standards, and using state adopted materials. Algebra achievement was measured when students had reached 70% completion of the course using the Assessment of Algebraic Understanding (AAU) published by Educational Testing Service (ETS). The AAU is a 50-item, multiple-choice test that was designed "for determining the extent to which students have mastered algebraic concepts. The items are aligned with the Algebra Standards as described by the National Council of Teachers of Mathematics (NCTM)" (ETS, 2004). The test can be administered according to any schedule. The reliability coefficient (KR-20) for the 2003 form of the Assessment of Algebraic Understanding is 0.8655.

The virtual school students who had reached the same point in the algebra course as face-to-face classroom students (70% completion) by the target date received a copy of the AAU exam, answer form, and consent form by mail. Students enrolled in classroom-based algebra courses taught in a public school in a district served by the virtual school also received the tests and consent forms during the same time period. The tests at all sites were administered according to the guidelines provided by Educational Testing Service.

Data Analysis and Results

The public classroom-based school had 97 out of the 98 students participate and complete the ETS AAU. Twelve out of 139 virtual school students completed the exam. A higher number of returned tests would be expected if the testing had been done later in the year when more students had reached the 70% completion point in the course, if the test could have been administered online, and if the course could have been designed from the beginning of the year to include the test as a requirement rather than as a voluntary activity. The ETS AAU full scores for the virtual group ranged from 19 to 32 while the full scores for the classroom-based group ranged from 10 to 33. Means for the ETS AAU full score were 24.08 for the virtual group and 19.43 for the classroom-based group.

The differences in the variability of the scores may be due in part to the larger, more variable sample of the classroom-based group and to the assessment being administered in a group setting within the classroom. Contrarily, the virtual school students completed the assessment individually, primarily at home, and at their own leisure. The voluntary participation of the assessment, the fact that the assessment did not count toward their school grades, and the test completion setting may be factors in the low completion rate of the virtual students. Further, the virtual students who did complete the assessment may be somehow different from the virtual students who did not complete the assessment. For instance, these students may be more academically motivated as well as naturally higher achieving than those who did not complete the assessment. Further, the virtual group may have had access to other resources at their disposal whereas the classroom-based group did not. Due to these assorted reasons, one should take care in drawing conclusions from the overall higher scores in the virtual group compared to the classroom-based group.

Interactive Tools for Graphing Linear Equations

Over time, mathematics educators at the Virtual School have identified five components of the algebra course that tend to be most problematic for students. One of the components, graphing linear equations, is the focus of this part of the study. Graphing equations is a representational activity, involving conceptual understanding of mathematical concepts, operations, and relations, along with strategic competence to represent the information (NRC, 2001, p. 257). To become proficient in any representational activity, students need to learn and use anticipatory thinking that comes from making meaning for the rules that will be applied. Students need experience generalizing, and the use of tools such as spreadsheets, graphing calculators, and graphing software can give students opportunities to explore relationships and develop generalizations.

An interactive toolset has been designed, developed, and reviewed. It was implemented and assessed with a sample of virtual school algebra students to address the problematic component, and the performance of these students on the component were compared to students who did not use the intervention. Newly designed and developed tools were embedded into the course's management system, enabling students to use the tools within the context of the lesson without leaving the course website to access tools at an outside website. The interactive tools were designed by a multimedia instructional designer using specifications developed by the virtual school mathematics specialist in consultation with the mathematics education and instructional technology specialist to address the objectives of the course module in which it will be used.

Tool 1 was designed to allow students to enter the coordinates of two points on a line. The tool provided the calculated answer and a graph of the line that indicated the rise and fall. The conceptual connection between the calculation, the points on the line and the meaning of slope should be enhanced. Tool 2 was a low level interaction that took students through a developmental series of screen shots designed to aid students in building their connections between the equations of lines, solution sets of the equations, and the graphs of the lines. Tool 3 allowed students to input the **m** and **b** values of a linear equation in y = mx+b slope intercept form, and the **a**, **b** and **c** values of an equation in ax + by = c standard form. Values for perpendicular and horizontal lines could also be entered. The tool provided the graphs of the lines. Two basic needs were met with this tool. First, students could see the graphs of lines allowing easy confirmation of their work. Second, students could change between the standard form of lines and the slope intercept form. Typically this change of form creates problems for students and they now have a mechanism for checking their work and getting immediate feedback.

To ensure that the course content would be equivalent for students using the new tools and students who would not have the tools, the two versions of the course were reviewed and aligned by the FLVS math specialist and the math education specialist. Two external reviewers rated the alignment between the module expectations and the module assessment. The reviewers were mathematics educators at public universities. Alignment was determined by using the multiple criteria described in detail in a National Institute of Science Education (NISE) research monograph, *Criteria for Alignment of Expectations and Assessments in Mathematics and Science Education* (Webb, 1997). In the first round of reviews, not all categories were judged to be in full agreement. After the assessment was revised, both reviewers judged the level of agreement to be "Full" for all categories. The degree of equivalency between the version of the Algebra 1 module with interactive tools for graphing equations and the version without the tools was rated by the outside reviewers, and found to be fully equivalent for four of six objectives.

Students registered for algebra course at the virtual school were assigned to the control group in which the interactive tools would not be used for the module on graphing linear equations, and the experimental group in which the tools would be used. Pre- and posttests containing 20 items on graphing linear equations were used as the performance measures for determining whether there was a difference between students in online algebra courses who used the digital intervention and those who did not use the digital intervention. If students scored above 80%, they moved on to the next course module. Students scoring below 80% participated in the module instruction. At the end of the module students took the post-test. Students who began the module during the first month of the study did not use the newly developed interactive tools. Students beginning the module during the second month used the new tools.

Data Analysis and Results

There were a total of 14 participants in the group without the graphing tool and 33 in the group with the graphing tool who completed both pretests and posttests. Pretest and posttest means for the group without the graphing tool were 17.50 and 19.21, respectively, and 15.02 and 18.08 for the group with the graphing tool. Gain scores were then calculated for the two groups. Gains were positive for both groups, indicating and overall improved score on the posttest as compared to the pretest. There was a mean increase of 1.71 points from pretest to posttest for the group without the graphing tool. Additionally, there was a mean increase of 3.07 points from pretest to posttest for the group with the graphing tool. This indicates that the students' performances in graphing linear equations increased from pretest to posttest when they were given the graphing tool intervention.

The results of the repeated measures ANOVA for the between subjects effects of Group were not statistically significant, $F(1, 45) = 0.32$, $p = .57 > \alpha = .05$. This indicates that the observed average difference between the group without the graphing tool and the group with the graphing tool is not different enough to conclude that a difference between these groups exists in the population.

The higher means in the group without the graphing tool may be due to the sample being half the size of the group with the graphing tool or because those students were somehow different from the group who received the graphing tool. For instance, these students may be more academically motivated as well as naturally higher achieving than those in the other group.

Implications for Teacher Preparation

Inservice teachers need a high level of detail related to instructional variables that enhance effectiveness of education approaches, and they need the skills for interpreting that data in a way that will translate to improvement in their own situation, whether it is online for face-to-face. In return teachers should consider opening their "classrooms" to researchers in order to continue the cycle of learning about learning. Teachers who teach online should feel confident that online algebra is an effective, equitable, accessible, and efficient course. Teachers who teach mathematics conceptually can take away from this study the idea that interactive manipulatives are effective for helping students develop abstract concepts.

Preservice teachers need the appropriate balance of content knowledge, pedagogical knowledge, and dispositions to succeed. Online teaching and learning differ in fundamental ways from classroom teaching and learning. In addition, the typical online algebra course has unique features that offer challenges for teacher preparation.

The virtual schooling community is beginning to recognize the bimodal nature of students served in online secondary courses. The majority of students fall into one of two groups. Many are younger than average advanced learners seeking acceleration in a subject area. Online courses appeal to them because they can have more control over the pace of their learning than they have in many classroom courses. For some advanced learners, online courses offer access to courses that may not exist in a regular school. The other group of online learners is an older than average group of students who need a slower pace and more individualized attention than may have been available in their classroom courses.

The algebra course described in this study is an excellent example of the wide student distribution. The minority of students enrolled in the course during the study were the 9th graders for whom the course was designed and intended. The students ranged from 6th through 12th grades, with a mean grade level of 9.4. Figure 1 shows the distribution of 124 students across grade levels. While 9th graders were the largest single grade level group, they did not represent the majority of the course enrollment.

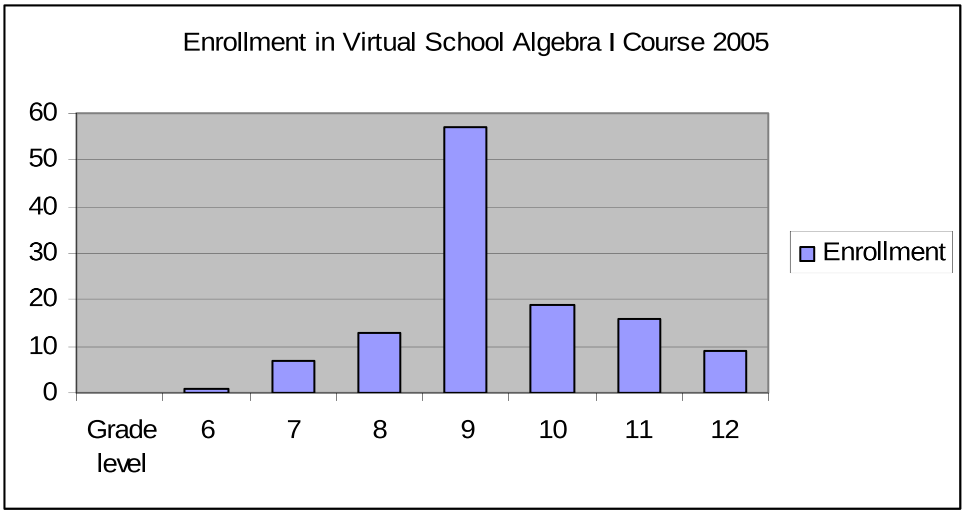

Figure 1. Grade distribution of online algebra students

Because the students sharing the same online algebra courses may be anywhere from 6th to 12th grade, or from age 10 to 20, the online algebra teacher needs an understanding of the developing mathematical mind across a range of development al levels. Recent evidence points to a positive association between a teacher's mathematical knowledge and his or her students' knowledge of advanced mathematical concepts (Mullens, Murnane, & Willett 1996). However, no association has been found between the number of advanced mathematics courses a teacher takes and the overall mathematics performance of that teacher's students (Monk 1994). A teacher's college major appears to be more strongly associated with his or her students' mathematical achievement than the number of mathematics course taken. According to NAEP data, eighth-graders taught by mathematics majors outperformed those whose teachers majored in education or some other field (Hawkins, Stancavage, & Dossey 1998). Because online algebra students function at eighth grade level and above, it seems reasonable that their mathematics teachers should have the equivalent of a mathematics major with attention to acquisition of fundamental concepts and principles.

In the case of the virtual school studied here, two of the four algebra teachers had majors in mathematics and two had majors in mathematics education. Both routes resulted in state certification and were supplemented with professional development on both mathematics education and online teaching. Three of the teachers had graduate degrees. While the largest online schools and the public online schools require certification in the subject area, not all online schools have this requirement. In addition, not all online schools require professional development in online teaching. A requirement that would professionalize virtual schooling would be for online teachers to have subject certification and an online teaching endorsement.

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