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Laptops, Technology, and Algebra 1: A Case Study of an Experiment

During the spring 2002 semester, an informal experiment at McNair Academic High School in Jersey City, New Jersey, dealt with the use of laptop computers as a teaching and learning tool in an algebra 1 class. One class of students used laptops as an integral part of their study of algebra, whereas a second class studied the subject in a traditional manner. This article reports on the experiment. It details how the study was conducted, the classroom approach taken by the teacher, problems encountered, the students' reaction, and so on.

The unique feature of teaching in a laptop classroom is that the instructor actually has two classrooms in one. With the laptop covers down, he or she has a traditional classroom; whereas with the covers up, he or she has a computer laboratory. The teacher can move seamlessly back and forth between these two environments and can exploit the strengths of each.

The unique feature of teaching in a laptop classroom is that the instructor has two classrooms in one

The conclusion of this article includes several recommendations that are based on the results of the study. A word of caution to the reader is appropriate before she or he reads this article. This study was an informal one, so statistics were not used in deriving our conclusions. The article is meant to be a narration of what the authors consider an interesting attempt to see how the use of laptops can enhance teaching and learning. The authors believe that this alternative considerably enhances the learning experience of students. Readers should view this article as a springboard to encourage educators who are familiar with traditional approaches to teaching mathematics to consider using this more technological approach.

MCNAIR ACADEMIC HIGH SCHOOL

The Ronald McNair Academic High School (MAHS) has been in existence since September 1976. It is a premier urban public high school whose bottom-line educational philosophy has been "academic excellence and nothing less." The school is structured for educationally oriented students who are preparing for professional careers. The philosophy of MAHS rests on the principle of the importance of a high-quality, integrated educational experience for students who are preparing for postsecondary studies. To support this principle, the school provides an intensive, comprehensive academic program taking place with an ethnically and racially balanced student body and staff. Of paramount concern is the development of each student's intellectual, social, and emotional growth.

Recognizing the current immersion of our society in technology, the administration and faculty of the school believed that considering a new approach in the manner in which education is delivered to students was imperative. With the goal of enhancing the learning experience of its students, MAHS undertook an informal study to learn how using laptop computers both within and outside the classroom can enhance the teaching and learning experience of students taking algebra 1.

STUDY DESIGN

The study involved two freshman classes that were taking algebra 1 in a four-by-four block schedule. (*Four-by-four* means that students take four classes in the fall and another four in the spring. Each class is eighty minutes long. Students can complete four courses every semester.) The experimental class consisted of twenty students, each of whom had the use of a laptop computer in school and at home. MAHS loaned laptops obtained from the New Jersey Department of Education to this group for the duration of the course. A comparison group of twenty-seven students did not use laptops in the classroom. However, many of these students were able

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to use their own computers at home. Both classes consisted of honors students and were homogeneously grouped according to ability. The study was conducted during the spring 2002 semester (February through June 2002). Victorina Wasmuth, a teacher of mathematics at MAHS, taught algebra 1 to both groups of students. Lawrence E. Levine, a professor of mathematical sciences at Stevens Institute of Technology, served as a consultant.

STUDY OBJECTIVES

This experiment was an informal one. Its objectives were to gain insight into how the use of laptops enhances the learning experience of students and to gain insight into whether any differences occurred in the learning achievement of the class that used laptops compared with the class that did not use laptops.

METHOD

The teacher used Discourse Instructional Delivery and Assessment Software with the laptop class. It provides real-time individual student assessment, thereby giving the teacher insight into each student's comprehension. The teacher can follow the students' learning in real time and assess comprehension while teaching.

Before the beginning of the semester, Wasmuth began identifying Web sites that were relevant and appropriate for algebra 1 students. She also reviewed and became familiar with the use of Scientific Notebook (SNB), a scientific word-processing package. When the laptops arrived, needed software was installed. A test was prepared to measure the technology skills of the students in both classes at the beginning and at the end of the study. Construction began on a comprehensive set of Web pages for both classes to use.

DURING THE STUDY

Both groups of students covered the same algebra 1 material at essentially the same pace. They also took the same examinations. Every attempt was made to keep educational aspects of the course the same, except, of course, that the experimental group used laptops. The approach to teaching the classes differed, however, because one group had laptops.

Both groups used technology. The comparison group was exposed to such technology as TI-82 calculators, Excel@Math software, The Geometer's Sketchpad, a computer with an Internet connection, a Smartboard, an LCD projector, and an overhead projector. The experimental group also used all the aforementioned materials. Homework assignments and projects were posted on the course Web pages. Both classes had access to Web links that provided lessons, mathematics problems, and detailed solutions to problems related to topics discussed in class. Each class met daily for eighty minutes, and the same tests were administered to both classes. The course content was based on the Jersey City Board of Education algebra 1 curriculum. Grades for the two classes followed the district grading policy in mathematics: 60 percent for tests, 20 percent for homework, and 20 percent for class activities.

TEACHING AND LEARNING IN A LAPTOP CLASSROOM

When Levine visited the MAHS classes in May 2002, he observed the two environments available in the laptop classroom: the traditional classroom and the computer laboratory. One of the topics that the class discussed was the properties of parabolas. This topic was introduced to the laptop group in a standard classroom setting with the laptop covers down. A number of examples helped the students master such concepts as the vertex and axis of symmetry of a parabola, the upward or downward opening of a parabola, and the minimum and maximum point. The teacher then had the students open their laptop covers, and the class proceeded to use the computer laboratory environment. The teacher pointed out that if a projectile is fired from the earth at a given velocity and a given angle and if friction is neglected, then the resulting path of the projectile is a parabola. The teacher told students to go to the course Web page and click on a link to a Java applet, www.phys.virginia.edu/classes/109N/more_stuff/Applets/ProjectileMotion/jarapplet.html.

This applet, which Levine had brought to the attention of the teacher at the beginning of the semester, allows the user to enter an initial velocity and angle of elevation and then click and view the resultant path of the projectile. The user can then change both the velocity and the angle and see the new trajectory. In this way, the students could experiment with different values of these parameters and see how they affected the path. The teacher then asked a number of leading questions to encourage the students to make conclusions about the interrelationship of these parameters and the trajectory.

It is important to understand that the nature of learning in the traditional classroom environment is different from that in the computer laboratory environment. In a traditional classroom, the learning is still primarily passive in nature for most, if not all, of the students, since information flows one way, from teacher to student. However, once the students had access to the simulation program on their laptops and on the Internet, the nature of the interaction changed, since students then had control of information that influenced output. However,

In a traditional classroom, information flows from teacher to student

when the teacher asked students to use their laptops to experiment with the simulation program on the Web, she had difficulty getting the students to close the laptops after the activity because they were so engaged in the study.

SCIENTIFIC NOTEBOOK

Scientific Notebook (SNB) Version 4 is a scientific word-processing program that incorporates a computer algebra system (CAS). A CAS allows users to perform a wide variety of mathematical applications, such as simplifying and evaluating algebraic expressions, factoring, solving equations and inequalities, solving systems of equations, performing matrix manipulation, graphing in two and three dimensions, differentiating, and integrating. Often the teacher gave students a problem, such as a polynomial to factor or graph, in class, asked them to solve it by hand, and then asked them to use SNB to check their results. At times, students used SNB to solve problems that were tedious or time-consuming to solve by hand, such as involved equations or complicated graphs. Outside of class, students were required to do their homework in SNB and then electronically submit their work to the teacher. These activities increased the computer fluency of the students and helped them become accustomed to using technology as part of their learning.

The software allowed everyone to participate at the same time in any given activity

DISCOURSE

One striking difference between the two classes was the use of Discourse Instructional Delivery and Assessment software in the class that used laptop computers. Discourse software provides real-time individual student assessment, thereby allowing teachers insight into each student's comprehension. Using computers, teachers can follow their students' learning in real time and assess their comprehension while teaching. As a result, they can instantly remediate, provide additional resources, and track and score results.

Once the students logged in, Discourse took over and an interactive communication began between the teacher and individual students. Everyone could participate at the same time in such activities as multiple-choice questions, true-or-false questions, solving word problems, free-response questions, or surveys. This software was used to assess the students' understanding of algebraic concepts and their proficiency on algebraic topics. It also enabled shy students to demonstrate their thinking skills without any fear of embarrassment in front of their classmates. When more than three students gave incorrect answers, the class closed the laptop covers and a student or the teacher demonstrated the correct procedure on the Smartboard or on the blackboard. The class-management program was also used to control every student's Internet access within the classroom. Its "world travel" feature assured the teacher that every student accessed only the Web site that the teacher had chosen. This feature is beneficial because students who are connected to the Internet face ever-present diversions—chat rooms, e-mail, browsing, and so on.

WEB SITE

Wasmuth developed an extensive Web site (located at www.geocities.com/wasmuthalgebra1) for all students who were taking algebra 1. The site contains links to class information, homework, grades, supplements, examinations and quizzes, and contact information. The "Class Information" link contains links dealing with the subtopics of proficiency (that is, the algebra skills that students are expected to develop), New Jersey Core Curriculum Content Standards in mathematics, and class policies. All the homework assignments for the semester were given on the Web, and students could access their grades over the Internet by using a password-protected script. The "Supplements" link contains sublinks entitled "Practice on Exponents," "Midterm Review," "Cool Math Sites," "Inequalities," "History of Algebra," "Class Project," "Fun Math Games," and "Formulas." Thus, the course Web site was a resource that students could use to study and to check their grades. Developing and maintaining such a site is, however, very time-consuming.

In discussions that Levine held with the students in the laptop group, the students indicated that the course Web site was a valuable resource. Indeed, a number of students expressed a desire to see similar sites for all their other courses. Students in the non-laptop group expressed similar sentiments.

STUDENT REACTIONS AND COMMENTS

Students in the laptop class expressed two major complaints. First, they complained that the workload carried by the experimental class was heavier than that carried by the "regular" class. Students believed that the discrepancy was not fair. After all, those in the experimental class were required to do all the work done by students in the regular class, as well as additional work related to using the laptop. Second, most students believed that the effort of transporting the laptop along with all books back and forth from school to home was excessive.

Below are comments that students made during the semester. Levine recorded some of them during his site visits, and others were responses on questionnaires that the teacher administered at the end of the course. These comments are, of course, anecdotal.

"The wireless network should be extended beyond the second floor to the entire school."

"We should be able to use the laptop in all of our other classes."

"I am using my laptop in some of my other courses."

"Why can't we have the textbook on a CD?"

"I now look at my laptop as a friend, and I do not want to give it back."

"All students taking algebra 1 should get Scientific Notebook."

"It (SNB) helps with my homework; it gives answers; it helps me check my calculations at home."

"If I see the answer (using SNB), I can sometimes figure out the solution myself."

"I like how it (SNB) helps you learn and gives you the solution to be sure you are right."

"It (SNB) serves as an at-home teacher if I don't understand my work."

"Graphing equations and watching them appear on the screen is fun, and it helps me have a better understanding of the problem."

"The Scientific Notebook works as a notebook, a calculator, and a tutor. It has various help files and a vast array of functions."

"Scientific Notebook gives us an answer, and we figure how to come up with that."

"It (SNB) helps you simplify and solve equations with or without variables."

"I haven't acquired other technology skills in the class, but I've never seen technology used to this extent. I never really used these technologies to do the things I do in algebra class."

"Everything acquired technology-wise, I already knew how to do. So I didn't learn anything that I didn't already know."

On each of his five site visits, Levine held a discussion with the students in the experimental class to learn their views about how the experiment was proceeding. During the first two visits, several students were apprehensive about the experiment and some were actually against it. However, as the semester progressed and as the students became familiar with the technology, their attitudes changed and became positive. Indeed, during the last site visit, the students overwhelmingly indicated that they believed that the experiment was a success. Many said that they would like to be able to use laptops in their other subjects.

FROM THE TEACHER'S POINT OF VIEW

Wasmuth's participation meant that she had to put in many extra hours outside the classroom, far more than a teacher who taught two "regular" algebra 1 classes. School districts need to remember that teachers must invest a considerable amount of additional time to prepare and use technology in their teaching. School districts should compensate teachers by giving them release time and other incentives. Wasmuth's observations included the following:

- Students in the laptop group spent more class time interacting and doing algebra, not just listening.
- Students in the laptop group spent more time on Web sites referenced on the class Web page.
- One student, who had the lowest grade (12) on the pretest, earned a high grade (88) on the posttest.
- Since students used e-mail to send homework and questions about it to me, I could often read their work before class, so I could come to class better prepared to address issues that were important to student performance. SNB, which eases the problems of preparing technical documents, facilitated this process.
- Students with laptops often spent part of their lunch break in the classroom doing algebra. When the laptops were turned in near the end of the course, only one student continued to do algebra during lunch. I attribute students' interest in using laptops for algebra to the Discourse software, which allowed students to have instant feedback to published exercises.
- E-mail also connected me more directly with parents, so parents could be informed in a more timely way of student progress or lack thereof. Through www.mygradebook.com, students and parents had access to grade reports, so I had more constant contact with parents, as well.

Students in the laptop group spent more time interacting and doing algebra

PERFORMANCE COMPARISONS

The performance comparisons are presented primarily to give readers a sense of the results rather than to prove them or establish their validity. No statistical analysis of the data has been made. Certainly, further experiments are needed and more careful analysis of the results is required before any broad-based conclusions can be reached.

Test scores and grades

Students in both groups were given a pretest to assess their knowledge of algebra 1 at the beginning of the semester. The same test was again administered at the end of the semester as a posttest. **Tables 1** and **2** give the pretest and posttest results. From these data, the authors draw the following conclusions:

- The average scores of both groups on the pretest and posttest show that the students knew a great deal more about the topics taught in algebra 1 at the end of the semester than they knew at the beginning.

TABLE 1
Laptop Group Pretest, Posttest, and Final Exam Scores

	Pretest	Posttest	Final Exam
1	64	100	98
2	32	96	97
3	48	88	88
4	52	100	100
5	68	100	100
6	56	96	78
7	44	80	68
8	20	68	47
9	40	92	90
10	48	96	94
11	36	88	84
12	48	92	93
13	Did not take	68	57
14	48	84	84
15	48	84	81
16	36	88	83
17	48	72	84
18	12	88	93
19	16	72	57
20	44	88	83
Average	43	87	83

TABLE 2
Comparison Group Pretest, Posttest, and Final Exam Scores

	Pretest	Posttest	Final Exam
1	60	72	63
2	32	88	93
3	32	92	83
4	48	96	86
5	60	96	99
6	24	80	80
7	36	88	78
8	52	84	74
9	40	68	67
10	36	72	83
11	36	80	52
12	56	68	63
13	28	84	81
14	12	92	91
15	36	80	81
16	56	48	29
17	32	68	72
18	32	92	89
19	48	100	97
20	24	76	74
21	44	92	88
22	48	84	84
23	8	76	49
24	52	84	89
25	36	72	64
26	24	84	89
27	28	84	70
Average	38	81	77

A dynamic learning experience almost invariably means that the students become better learners

- The average score of the laptop group on the posttest exceeded that of the comparison group by six points.
- The average score of the laptop group on the final examination was six points higher than that of the comparison group.

Thus, although both groups of students mastered the topics presented in algebra 1, the performance of the laptop class appears to have been somewhat better than the performance of the comparison group. However, the differences in average scores may not be statistically significant and should not be construed as such.

Initial and final technology surveys

At the beginning of the semester, each student in both groups was given a questionnaire, shown in **figure 1,** to measure his or her technological level. The same questionnaire was administered at the end of the semester. The questionnaire consisted of twenty-four questions. The responses on the pretest and posttest for questions 1 through 16 were essentially the same for both groups of students. That result is not surprising, since almost all the students had been using computers before they took algebra 1. The responses to questions 17 through 22 seemed to show the greatest change. All students in the laptop group answered yes to questions that deal with the benefits of using a CAS, such as that included in SNB, in algebra 1. About 50 percent of those in the comparison group responded yes. Since that group did not have access to laptops during the course, this result is not unexpected.

The data from these surveys, as well as teacher observation, indicate that the technological level of the laptop group had increased considerably. As the semester proceeded, the teacher observed that students in the laptop class showed an increasing level of comfort with the use of computers. These students are well on their way to achieving computer fluency, which will be valuable to them throughout their higher education and when they enter the workforce. Thus, the use of laptops in and outside the classroom is an important tool for a school like MAHS in preparing students who need to be competitive in an increasingly technological world.

EQUIPMENT PROBLEMS

Surprisingly enough, relatively few problems were related to the functioning of the laptops. When a laptop needed repair, the student who was using that laptop was given a loaner. Several laptops were set aside for that purpose, and we strongly recommend that any school intending to implement a laptop classroom have several laptops that are designated as loaners.

As previously mentioned, each student was loaned

Technology Survey

1. I have a computer in my home. Yes ☐ No ☐
2. During an average week, I use the computer in my home Every day ☐
   4 or more times ☐ 2 or 3 times ☐ Once ☐ Less than once a week ☐
3. During an average week, I use a computer (not necessarily one at home) Every day ☐
   4 or more times ☐ 2 or 3 times ☐ Once ☐ Less than once a week ☐
4. My main use for a computer is to play games, to watch DVDs, or to instant message my friends. Yes ☐ No ☐
5. My main use for a computer is for educational purposes. Yes ☐ No ☐
6. The level of my knowledge of computers is Expert ☐ Fairly knowledgeable ☐
   Somewhat knowledgeable ☐ Elementary ☐
7. I use a computer to help me with my schoolwork. Regularly ☐ Often ☐
   Sometimes ☐ Rarely ☐ Never ☐
8. I know how to create a new folder on a computer. Yes ☐ No ☐
9. I know how to download and install a program on a computer. Yes ☐ No ☐
10. I know how to save a file to a folder. Yes ☐ No ☐
11. I have used a computer program to help me with my schoolwork. Yes ☐ No ☐
12. I know how to search the Internet to find information about a topic. Yes ☐ No ☐
13. I have searched the Internet to find information about a topic. Yes ☐ No ☐
14. I have searched the Internet to find information about a topic to help me with my schoolwork. Yes ☐ No ☐
15. I think that using computers inside and outside the classroom will enhance my learning of mathematics. Yes ☐ No ☐
16. I think that using computers inside and outside the classroom can enhance the learning of any subject. Yes ☐ No ☐
17. I know what a computer algebra system (CAS) is. Yes ☐ No ☐
18. I have used a CAS to help me with mathematics. Yes ☐ No ☐
19. I have used a CAS for graphing. Yes ☐ No ☐
20. I have used a CAS to solve systems of equations. Yes ☐ No ☐
21. I think that using a CAS can help me check my calculations at home. Yes ☐ No ☐
22. I think that using a CAS can help me check my calculations in school. Yes ☐ No ☐
23. I think that using a CAS can give me self-confidence in class. Yes ☐ No ☐
24. If you have used a CAS, then please indicate what you like about it below.

Fig. 1
Technology survey

a laptop that she or he was expected to bring back and forth from home to school daily. There was, of course, a good deal of concern about possible loss of a laptop. To deal with this situation, a parent of each student was required to sign a contract with the school guaranteeing that in the case of loss, the parent would pay the cost of replacement. Only one laptop was lost, and that laptop was stolen.

RECOMMENDATIONS

On basis of the data, the students' reactions, and the experiences and observations of Wasmuth and Levine, the authors believe that this study shows that decided benefits exist when students use laptops both in and outside the classroom. Students using laptops not only benefit from the familiarity that they gain with technology, but they also experience a more active learning environment when the laptops are used for hands-on classroom reinforcement. This involvement in the learning process is very difficult to foster in a traditional classroom environment. Since a dynamic learning experience almost invariably means that students become better learners, the use of laptops both inside and

outside the classroom should be incorporated into the fabric of teaching at the high school level. Levine made the following recommendations to MAHS.

- The use of laptops should be extended. As many students as possible should be given laptops to use in their studies the following year.
- Wherever possible, textbooks should be available to students both in hard copy and CD versions.
- The use of laptops in algebra 1 should be extended to all groups of students taking that course.
- If possible, other mathematics courses should be taught with laptops.
- The use of laptops should be extended to other disciplines. Teachers of other subjects should be encouraged to incorporate technology in their courses wherever possible.
- MAHS should establish a goal that every student should use a laptop in every subject within the next few years.
- The wireless network at MAHS should be extended throughout the school building so that students can use it anywhere in the building.
- Secure areas for laptop storage should be provided to students.

Students need to be comfortable with the use of computer technology

CONCLUSIONS

The use of laptops and other technology in the teaching and learning of algebra 1 at MAHS added new dimensions to the way that students studied this subject. Although the active learning environment was certainly not the only benefit, it is of great value. This benefit is not limited to algebra 1 and can certainly be fostered in the study of other mathematics subjects and in other disciplines.

High schools must prepare their students so that they can function and be competitive in today's increasingly technological world both in college and in their careers. Students therefore need to be comfortable with computer technology in their learning and future work. One way to reach this goal is to integrate the use of laptops and other technology into the teaching and learning experience.

Further studies are required before the overall implications of teaching mathematics and other subjects in a laptop classroom are clarified and fully understood. Although this one experiment does give some insight into the ways that laptops affect teaching and learning in the classroom, it is not meant to be used as a basis for making sweeping recommendations about the use of laptops. However, it is a beginning. The authors hope that other high schools will set up similar experiments to study the effects of incorporating laptops into their academic programs. A clearer picture of the positives and negatives of using laptops in the classroom should then emerge. Armed with this information, educators can make intelligent decisions about the use of technology by their students.

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