Can Educational Software Really Have an Impact on Student Performance?

Abstract

This article describes action research that was designed to explore the effects of instructional technology on student performance related to the statewide mathematics curriculum. The study examined student performance as a dependent variable and Master Guru software practice time as an independent variable while maintain the authenticity of curriculum administration in the classroom. Beyond the quantitative analysis, researchers triangulated quantitative data with a student survey and teacher interviews in order to qualitatively explore the students' interface with the Master Guru software. Findings are connected to the current literature and provide a context for better understanding the intricacies of incorporating instructional technology for student achievement.

Introduction

With the newly created National Educational Technology Standards (NETS), teachers are called to incorporate instructional technology into their classroom practices and students are being asked to demonstrate their ability to use technology for a multitude of purposes. Creators of the standards indicate the necessity of teachers to be well prepared to teach in the 21st century: "Today's classroom teachers must be prepared to provide technology-supported learning opportunities for their students. Being prepared to use technology and know how that technology can support student learning must become integral skills in every teacher's professional repertoire" (International Society for Technology in Education, 2002, p. 2).

The NETS explicate the incorporation of instructional technology at each developmental level. Specifically, these standards require students at the Pre-K-second grade level to be able to "use a variety of media and technology resources for directed and independent learning activities and use developmentally appropriate multimedia resources to support learning" (International Society for Technology in Education, 2002, p. 4). In grades 3-5 students need to be able to "use technology resources for problem-solving, self-directed learning, and extended learning activities" (International Society for Technology in Education, 2002, p. 4). By middle school and high school, students need to be able to "select and use appropriate tools and technology resources" (International Society for Technology in Education, 2002, p. 4). One way teachers at all grade levels have integrated technology in order to help students meet these standards is through the use of educational software. Notably, it appears that many teachers use software in the spirit of

NETS compliance without the skills to, or direction on ways, to effectively incorporate educational software into curriculum or effectively evaluate software quality and educational utility.

In tandem with the development of technology-related standards has been the development of content-based standards at both the national and state levels. Professionals within each content area have developed national standards to guide classroom practice (e.g., National Council for Teachers of Mathematics, 2000; National Council for the Social Studies, 1994; National Science Education Standards, 1996; International Reading Association, 1996). Educators have used these standards as a guide as statewide standards have been developed. Teachers are now held accountable for ensuring that students in their classrooms are making progress towards these developmental standards. Many researchers and practicing teachers agree that the integration of technology into the national educational agenda is critical. However, little research has been done to investigate the efficacy of specific technological applications (e.g., software) in the instruction of specific content areas (e.g. math).

Purpose of the Study

This action research was designed to explore the effects of instructional technology on student performance related to the statewide mathematics curriculum. The study examined student performance as a dependent variable and Master Guru software practice time as an independent variable while maintain the authenticity of curriculum administration in the classroom. Beyond the quantitative analysis, researchers triangulated quantitative data with a student survey and teacher interviews in order to qualitatively explore the students' interface with the Master Guru software.

Review of the Related Literature

Classroom practices have yet to reflect the agendas and efforts of policy makers, funded proliferation and educational programs, and empirical findings. Research indicates that only thirty-one percent of students reported using computers in school (Ruthven & Hennessey, 2002) and only 20 percent of teachers feel comfortable using technology in their classrooms (US Department of Education, 1999). It appears that instructional technology is not being readily incorporated into classroom practice despite the multitude of financial and time investments in teacher in-service workshops, continuing education teacher training, and other school-wide efforts (e.g. Federally funded Preparing Tomorrow's Teachers for Technology grant program). In addition, the focus of a substantial portion of the research conducted on technology integration has been the examination of 'innovative situations' (Ruthven & Hennessy, 2002, p. 48), rarely integrated in to the typical classroom. While many teachers use computers to "provide practice of skills" (Becker, Ravitz and Wong, 1993, p. 13), there is a need for a more sensitive interface between the national technology agenda, research, and actual classroom practices. This study provides a more contextualized snapshot of the impact of a typical way in which teachers integrate technology into their classroom practice.

Impact of Technology on Student Achievement

The research on student achievement related to technology-enhanced learning has favored the use of computers in the classroom. Kulik (1994) did a meta-analysis of 500 research studies on computer-based instruction. Data indicated that students who used computer-based instruction outscored students in the control group on standardized tests. Additional benefits of computer-based instruction were indicated including opportunities to learn more content in the same amount of time as traditional instruction and positive increases in student attitudes towards their classes (Kulik, 1994). These findings were further supported by Sivin-Kachala's (1998) review of 219 research studies on computer assisted instruction that also revealed that student achievement in content areas was increased by the use of computer technology and that students had a more positive attitude towards learning. Similarly, Wenglinski (1998) found that higher order uses of computers led to increased student achievement in mathematics for both fourth and eighth grade students. Further, Wenglinski (1998) found that students who had teachers that participated in technology based professional development had higher levels of academic achievement. There is a growing consensus in educational research that application of educational technology can enhance learning.

To date, software has played a prominent role in the infusion of technology in the classroom (Batanov, Dimmitt, & Chookittikul, 2002). For example, Ruthven and Hennessy (2002) reported in their case study research "the predominant form of computer use was of drill-and-practice [software] packages to consolidate step-by-step procedures for solving standard types of problems" (p. 49). Analysis of the cognitive processes in learning suggests that the instructional efficacy of educational software may come from the question/answer approach embedded in most computer learning models and packages (Batanov, et al., 2002). Further, the most effective question/answer formats utilize a purposeful strategy aligned with learning objectives (Batanov et al., 2002). To illustrate outcomes, Henderson, Klemes and Eshet (2000) report findings that indicate using simulation software with second grade students had an effect on the cognitive outcomes and processes over a six-week period. Findings indicated improvement in thinking skills and strategies ranging from basic recall to higher-level skills (e.g., classification and inference; Henderson, et al., 2000).

Action Research

Research has indicated that teachers' beliefs and confidences may play a bigger part in whether actual change results from efforts to incorporate technology into classroom practice (Ertmer, Addison, Lane, Ross, & Woods, 1999). Because of their influential role, focus should be placed on involving teachers "in discovering and testing how it can improve student achievement…examining the effectiveness of teaching with technology" (Royer, 2002, p. 2). As action research (e.g. Belanger, 1992), this study engaged teachers in examining whether a piece of educational software could impact student achievement and performance on a statewide mathematics exam.

About the Educational Software: Master Guru

Master Guru (MG) is a piece of educational software focused on the New York State Learning Standards and designed to build critical thinking skills. A self-reported preparatory tool for the New York State Exams in math, science, social studies, and English Language Arts, this software is aimed at helping teachers develop learning opportunities for students across all elementary grade levels. This software goes beyond typical skill and drill, meeting the best practices qualification: question/answer format aligned with content standards (Batonov et al., 2002). Further, when a question is answered incorrectly, the student is provided with the correct answer and an explanation of why the answer is correct. In this way, the software is intended to provide learning opportunities as well as practice.

Research Methodology

Procedures

Participants. Students and teachers in four, fourth grade classrooms at a rural elementary school in Western New York served as the participants in this study. The 90 participants included 45 males and 45 females with ages ranging from 8-10 that were randomly assigned to one of four classrooms at the beginning of the school year. Each of the four classroom populations integrated regular as well as special education students. The participants in this school were recruited following expressed interest in studying the effects of instructional software on student performance.

Research Procedure. The researchers worked with each teacher to carry out the procedures of the action research design. Each day, students received math instruction connected to the statewide fourth grade curriculum guidelines. Teachers were not asked to modify their normal math instruction during the course of the day. A quasi-experimental post test only control group design was used (Campbell & Stanley, 1966). The Master Guru software was utilized for the two classes in the treatment group while students in the two control group classrooms did not use the educational software. Students in the treatment group logged onto the math portion of the Master Guru software for one hour each week for 10 weeks prior to the administration of the statewide math exam. The researchers did not require that students use the educational software for specific amounts of time per day: each teacher determined, within the context of their classroom schedule, how students would meet the time expectation each week.

At the end of the study, students were administered the statewide mathematics examination to determine their mathematical aptitude. Immediately following, students were asked to complete a brief questionnaire. The questionnaire asked students to rate various aspects of the Master Guru software as well as their perceived impact of using the software on their performance on the statewide exam. Throughout the 10-week study, participating teachers in the treatment group were asked to keep reflective journals; noting observations about the research procedure as well as observations of students while using the Master Guru software. In an effort to gain more in-depth understanding of the practical implications of using this software, action research teachers were interviewed together about their experiences. The interview included structured questions as well as unanticipated questions that flowed from the discussion.

Data Analysis. For each of the variables identified on the student survey as well as the study variables (mathematical standards score ratios and total math scores) in the study descriptive statistics were calculated. In order to assess the effects of use of MG software, gender, and possible interactive effects on the mathematics performance of fifth graders, a Multivariate Analysis of Variance (MANOVA) was calculated. Once these effects were analyzed, Univariate F tests were conducted for the seven dependent variables representing mathematical performance. Next, mean differences were analyzed in order to assess the direction of differences. Interviews and teacher journals were reviewed for common themes or information that may substantiate or complement the statistical findings.

Quantitative Results

Of the 90 fifth grade students who took the mathematics test at the study site, 35 students used the MG software and 55 did not. The 35 students who used MG were divided into two classrooms (17 students/18 students) representing the total populations of these two classrooms. Forty-five of the students were female and 45 were male. Both genders were represented evenly in each of the classrooms.

Survey data analysis. The MG user survey was completed by 33 of the 35 students who used the MG software to prepare for the mathematics exam. All students identified many other ways that they prepared for the mathematics test: class review (84.8%), Power Up (12.1%), math centers (75%), math homework (93.9%), math lab (84.8 %), practice exams (87.9%), hands on math manipulative (78.8%), and math class (87.9%). Most students (75.8%) stated that they believed that MG helped them get ready for the mathematics test. When asked what they thought of MG, students made positive and negative comments about the software: characters (83.9% positive and 16.1% negative), levels (71.4 % positive and 28.6 % negative), and graphics (92.6% positive and 7.4% negative). Approximately 54% of the students said that if they were creating MG they would keep the characters, 11.5% stated that they would keep the subjects and graphics respectively. Another 11.5% said they would keep everything and 7.7% stated that they would keep only the subjects and characters. When asked what they would change, 35.7% reported that wanted more levels, 25% wanted new characters, 17.9% would add new subjects, 17.9% stated that they would make it harder, and 3.6% said that they would add more action. Of the responders, 45.5% described MG as easy, 24.2% described MG as moderately difficult, and 18.2% said it was hard. Seventy-two percent reported that they found MG helpful for preparing for the mathematics exam. Overall, 81.8% said that they would use MG again.

Mathematics performance data. The set of seven dependent variables representing the students' performance on the items representing the seven mathematics standards (mathematical reasoning, number and numeration, operations, modeling/multiple representations, measurement, uncertainty, and patterns/functions) were used to measure mathematical performance. The Multivariate Tests (Wilks' Lambda $p < .05$) indicated that there were no interactions among the set of seven dependent variables, gender, and software. Further, main effects indicated that there was no gender main effect and gender was not significantly related to mathematical performance. However, software produced a significant effect indicating that there was a significant relationship between use of software and the set of seven dependent variables. Given the significant main effect for software, Univariate F tests were conducted for the seven dependent variables. Software was found to be significantly related to the students' performance in both mathematical reasoning ($p = .009$) and patterns/functions ($p = .028$) standards. Group descriptive statistics were generated to demonstrate the direction of the relationships. For mathematical reasoning, the group that did not use the software ($\underline{M}$ = 74.4 % correct) performed significantly better than the group that used the software ($\underline{M}$ = 62.9 % correct). Conversely, for pattern/function, the group that used the software ($\underline{M}$ = 55.4 % correct) performed significantly better than the group that did not use the software ($\underline{M}$ = 45.5 % correct).

Summary of statistical findings. Analyses of the data indicate that there are a few differences in mathematical performance on the state-wide exam between students who used Master Guru software and those that did not. In the two areas of the exam in which there was a significant difference, students in the software group outperformed students in the control group in the area of patterning and mathematical functions and under-performed students in the control group in the area of mathematical reasoning.

Qualitative Findings and Interpretation

This study was designed to determine if educational software could have an impact on the achievement of students in mathematics. Different from previous studies that have been done, this research applied a qualitative aspect in order to incorporate participants' interpretations and perceptions of their experience. Both students and teachers were asked to reflect on their experiences with using the educational software to share their perceptions. Not only do the findings become more meaningful in interpretation, but they also become more applicable to real life classroom situations. We only asked those who used the software to reflect on their experience using this method of instruction. Data from the teachers' interviews and journals along with the open-ended questions on the student surveys are applied to the data in an effort to more accurately interpret findings. Observations by teachers as noted in their journals and during the interview provide a broader perspective about the impact of this educational software on the students.

Understanding the statistical findings. Statistical findings were reviewed and compared to qualitative information. This process helped to enhance interpretation of statistical analysis as well as provide additional information about he efficacy of software use in the classroom not measured by quantitative assessment. Although statistical findings indicated no overall significant differences between the groups that used software and those who did not integrate to math achievement, there are many teacher and student indicators beyond the quantitative analysis that would suggest a level of utility in the software not reflected in statistical outcomes. Teacher data and the responses in student questionnaires indicated that both teachers and students thought MG helped them prepare for the math exam. Specifically, in interview and journal data teachers described many positive math outcomes and 72% of surveyed children indicated that MG was helpful.

Significant statistical findings were also explored. Interestingly, students using the software demonstrated higher achievement in the area of patterning and function and lower achievement on questions that were related to mathematical reasoning. Positive outcomes are consistent with qualitative student and teacher data. Negative mathematics reasoning outcomes did not fit qualitative data. In contrast to statistical outcomes, data from the teachers' interviews indicates that one of the benefits of using this software that they observed was how it helped students develop their problem solving. One teacher states,

> I do think Master Guru increased the children's understanding of problem solving in particular. I like the fact that a lot of my kids had trouble deciding what operation to do based on a problem, for instance is this word problem asking me to add, subtract, etc. and I noticed that skill got better. I think Master Guru really helped with that. I saw a lot more kids think it out, whereas they seem to take an instant guess when we do it in class. After getting it wrong and after all the repetition they start to think.

One possible explanation for the discrepancies was provided by another teacher,

> The Master Guru doesn't have the capability to have the kids show their work and explain their answers. That is something that the New York State test has the kids do. It was good practice for problem solving and thinking skills, but to say that the kids could show their work and explain their answers…they couldn't do that. So, does it totally one hundred percent parallel the NYS test, I'd have to say no.

That is, the cognitive problem solving observed by the teachers as the children responded to the MG software is qualitatively different form the problem solving measured by the NYS Math test. So, students may have improved in ways not measured well by the test. Other explanations are many. It is possible that some cognitive skills respond better to this type of drill, practice, exploration, and repletion than others. Also, the MG program may have varied question or take quality with some sections better developed and consequently more effective than other sections. It is clear from these data that the qualitative data provide a broader perspective about software use than the quantitative data provide alone.

Affective outcomes of using software. The teachers noted a number of other unanticipated outcomes of using the software with the students. First, teachers observed that the **students were excited** on the days they used the software. It was something they looked forward to and were enthusiastic about. One teacher explains, " They didn't realize that they were actually learning something, but they were. I would say 'let's take a break, let's go play Master Guru' and they would be like 'woo-hoo!' Teachers indicated, almost daily, in their journals that the students were excited to be using the software and it increased their interest in learning. In the surveys, students indicated that they liked using the software to "learn math." The graphics provided on the software were engaging for the students and kept their interest. This finding supports Sivin-Kachala's (1998) and Kulik's (1994) extensive reviews that educational technology increases students' positive attitudes towards the subject.

Second, teachers indicated that the software exposed them to **different thinking skills and applying concepts in different way**. Using the software exposed the students to different ways of using their knowledge to demonstrate higher level understanding of the mathematical concepts. One teacher described,

> I think it exposed the kids to a lot of different thinking skills. Sometimes when you are trying to teach the basics skills of math you don't get to those areas or application. I think there were a lot of random questions that you wouldn't think of doing with the kids. It exposed them to unique things. A lot of things you wouldn't get from just the book. Like the three dimensional shape figures, they really had to think about what we had learned and apply it in a picture.

Because of this exposure, students have the opportunity to benefit from a "second teacher;" the software. In some cases, the software program had the capability to demonstrate mathematical concepts in ways the teacher did not. The technology allowed students to apply math to multiple examples and problems.

Third, reinforcement provided by the software offered a **source of motivation** for the students; even students that did not always experience success in regular classroom activities. One teacher explains,

> The frustration level is more in the classroom, with the computers they felt like they were challenging themselves. Even with the lower kids, they wanted to get more right, they had intrinsic motivation. I saw a lot of kids getting personal rewards, being proud of themselves. They weren't competing against their neighbor, it was for themselves. And I saw a lot of kids getting proud of themselves. There were a lot of personal rewards.

Utilizing this software for practice and reinforcement created a "novel" approach to learning math. The highly responsive, attentive, and individualized nature of the software tool provides a consistent feedback system that cannot be matched by human effort. That is, as a child sits to play MG each response they make is quickly assessed, responded to, and explained. If they are correct, the are, item-by-time as well as cumulatively, reinforced, and there performance is recorded. Further, the children are active directors of their learning choosing challenges, winning levels, and taking chanced in a very private and secure learning space (one-one-one with the computer). These types of learning experiences may be a unique pedagogical contribution of software not fully explored in the research. Further, these characteristics may be especially effective for the individual, anxious, or private learner. Finally, research indicates that using multiple strategies for teaching and reinforcing content increases student learning and retention (Joyce, Weil & Calhoun, 2000; Gardner, 1999). The software adds a layer of strategic diversity.

Summary of Findings. Findings from this study suggest that while statistically defined efficacy is unclear, researchers must look beyond generalizing that all software provides positive achievement gains to determining how it impacts learning and that software provides affective benefits that may, in turn, affect the academic gains it provides. Using a posttest only design, statistical findings did not result in significant between group differences. However, student and teacher qualitative data do indicate that the affective outcomes did have a positive impact on the learning experience of these fourth graders. Specifically, students and teachers reported that students were excited about learning using the software, exposed them to thinking about math in different ways, and provided a source of intrinsic motivation for students learning math (e.g., 81% of student reported that they would use the software again). As indicated by these triangulated findings, one type of data may not show the entire picture when considering the impact of using educational software in the classroom.

Discussion

Implications. There is a great deal of research that indicates the positive impact of educational software on the achievement of students and in their attitudes towards school (Kulik, 1994; Sivin-Kachala, 1998). This study adds to this knowledge base, not in the sense that it completely supports it, but that it may cause researchers to continue to examine the conditions under which educational software has an impact on student achievement. In addition, this study certainly causes educators and researchers to consider the affective impact that using educational software can have and student motivation and interest in learning.

Limitations of study. The attempts to generalize the findings of this study are compromised by the following limitations. First, in the effort to represent real-life elementary classroom situations, students and teachers from four classrooms were participants and the research design was structured to consider the natural teaching and learning conditions that apply to the instructors and classroom life for each particular setting, but may have limited the structuring of the software activities. While the math curriculum and amount of time devoted to mathematics instruction during the study were consistent across classroom settings, we could not control for the teaching style of each teacher or the day to day activities that took place. As evident from the teachers' journal entries, there was occasion when students were not able to complete one hour of software time per week. Second, it is difficult to say if the children in the two software utilizing classrooms were involved in other learning experiences that may have interacted with MG effects. Third, because this was a posttest only assessment we cannot be sure if the treatment groups differed in regard to math aptitude and math background knowledge before MG implementation. Fourth, responsiveness to the MG software was also not measured. It is possible that some types of students show a better responsiveness or better trajectories of improvement in responsive to software applications than other students. Finally, with a sample size of 90 students, all from one elementary school, it may be difficult to generalize findings to others educational settings. It may also be possible that 10 weeks was simply not enough time for the software to impact student achievement.

Questions for further research. A number of questions for further research were generated as a result of carrying out this study. Mostly, these questions focus on the day-to-day implications for teachers utilizing educational software in their classroom. How do the affective outcomes of using educational software impact the academic achievement of students? How does the quality of educational software impact student achievement and affective outcomes? How can a teacher identify good educational software from poor? What amount of time does a teacher need to have children spend for software to have an academic and affective impact? What qualities does the educational software need to include in order for it to have an academic and affective impact? Are there pedagogical qualities of software that suit a particular type of student? These questions address research that will provide teachers with practical implications that can be used to transform teaching practice that integrates instructional technology.

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