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A Brief Overview on Using Technology to Engage Students in Mathematics

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Incorporating and using technology in teaching mathematics can encourage students to become active participants in the classroom. This paper gives a brief overview of several technologies that can be used to enhance learning and motivate students to become engaged in the learning process. The technologies discussed include graphing calculators and computer-based tools such as presentation software (PowerPoint) and computer/web-based instruction and practice. Appropriate use of technology will get more students to think and reason mathematically; but, technology in and of itself is not a panacea that will resolve all students' struggles.

Keywords: technology in mathematics, web-based instruction/practice, enhancing mathematics learning, graphing calculator technology, teaching/learning strategies

Motivating students in mathematics courses can be a challenging task. Research findings suggest that when students are actively involved in the learning process, it leads to increased student learning and persistence, higher grades, and more thorough questioning (Felder, 1992; Bonwell & Eison, 1991). Incorporating and using technology in the teaching of mathematics can encourage students to become active participants in the classroom.

Several studies (Ng & Gunstone, 2002; Dunham & Dick, 1994; Pomerantz, 1997) found technology could motivate students to learn mathematics. Souter's (2001) action research study examined five algebra classes involving four teachers and 92 ninth-grade students. He compared the effects of technology-enhanced algebra instruction with traditional algebra instruction and determined that integrating technology into mathematics can increase student achievement and motivation, foster positive student attitudes, and enhance student outcomes. After in-depth interviews and classroom observations of five middle school teachers from three middle schools in rural Pennsylvania, Kim, Grabowski, and Song (2003) concluded that using internet resources leads to active learning and motivates students to engage in the learning process. When graphing calculators are included in the learning process, students can approach problems using techniques that suit them best, which results in better performance and increased confidence (Quesada, 1996). Presentation software such as PowerPoint leads to increased student motivation and better positive attitudes when students attend lecture classes (Susskind, 2005).

Within the past few decades, the use of technology in the classroom has been rapidly increasing. The use of calculators and computers is widespread and technology-enhanced classrooms are more prevalent. In Principles and Standards for School Mathematics (2000), the National Council of Teachers of Mathematics (NCTM) states "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). They feel technology should be accessible to all students, but should not be used to replace basic understandings. The use of technological tools "cannot replace conceptual understanding, computational fluency, or problem-solving skills" (NCTM, 2008, p. 6). However, "when technological tools are available, students can focus on decision making, reflection, reasoning, and problem solving" (NCTM, 2000,

p. 24).

Recent evaluation studies suggest that instructional technology is thriving and can also make teaching more effective (Kulik, 2003). Various other research studies have examined the impact of technology on student learning and found its use is associated with skill development, content mastery, and increased exam scores (Strayhorn, 2006; Hofman, 2002; Kulik & Kulik, 1991). Wenglinsky (1998) analyzed data from the 1996 National Assessment of Educational Progress (NAEP) in mathematics, which included 6,227 fourth-graders and 7,146 eighth-graders. In his quantitative study, he found that technology did make a difference in academic achievement. Wenglinsky also found that how the technology was used and teachers' professional development in technology mattered. In his quantitative study, Strayhorn (2007) used nationally representative data from the National Study of Postsecondary Faculty to examine how and to what extent higher education faculty used technology in the classroom, and found there was room for improvement. Using a sample of approximately 1400 higher education faculty, he found that 59.4% of all higher education faculty used email rather than websites or a combination of the two. Strayhorn (2007) suggests faculty should create course websites to enhance student learning and use more than one form of technology in their teaching.

A number of different technologies are being used in mathematics classrooms with varying degrees of success. The term "technology" can mean a variety of things from pencil and paper drill and practice exercises to tutorials on computers. In this paper, technology refers to graphing calculators and computer-based tools such as presentation software and computer/web-based instruction and practice.

Graphing Calculator Technology

The first hand-held calculators appeared in the early 1970's and could perform basic four-function operations. These simple calculators have evolved into ones that graph functions, manipulate algebraic expressions, solve systems of equations, and differentiate and integrate. Graphing calculators are more prevalent in the classroom than other forms of technology due in part to affordability and accessibility. These calculators are valuable tools that allow students to achieve higher levels of conceptual understanding and expand their problem solving and critical thinking skills. However, teachers still debate whether or not to include the use of graphing calculators in the classroom.

Many research studies have confirmed the value of calculators in the classroom. Dunham's (2000) review of research confirms graphing calculators can enhance mathematical instruction, empower students to become better problem solvers, facilitate improved teaching and learning, and increase mathematical achievement. In their meta-analysis of 79 studies to assess the effects of calculator use on student achievement and attitude, Hembree and Dessart (1986) reported that students who use calculators along with traditional instruction maintain their paper and pencil skills with no apparent harm, and calculator use improved the paper and pencil skills of students regardless of their ability levels. Their quantitative analysis also found testing with calculators produced higher achievement scores in both basic computational skills and problem solving. Research analyzing the results of a meta-analysis of 88 studies on the effects of pre-college calculator use reported that calculator use did not hinder students' acquisition of conceptual knowledge (Hembree & Dessart, 1992). Additionally, calculator-enhanced instruction in the classroom increased test scores for low and average students. Smith's study (as cited in Barton, 2001) extended the results of Hembree and Dessart's research and concluded calculator usage had a positive effect in problem solving, on increasing conceptual knowledge, and in computation. His review of over 30 studies from 1984 to 1995 found students who used calculators had significantly higher achievement in mathematics and a significant difference also existed in students' attitudes. Smith also found calculator usage did not hinder the development of paper and pencil skills. Waits and Demana (2000) feel a balanced approach of using paper and pencil along with calculators is essential to the teaching and learning of mathematics. Traditional arithmetic and algebraic skills are still important; however, students should understand why procedures work on an intuitive level before resorting to using the calculator (Waits & Demana, 2000).

Technology, such as the graphing calculator, allows students to explore more difficult problems and mathematical concepts in more detail. Graphing calculator usage reduces time spent on tedious paper and pencil computations and allows students and teachers to spend that time developing deeper conceptual understandings and problem solving skills. When students use graphing calculators, they are more willing to engage in problem solving, use more strategies for solving problems, and increase their achievement (Suydam, 1985). In a quasi-experimental study involving three eighth-grade general mathematics classes in a southeastern Virginia middle school, Merriweather and Tharp (1999) investigated the effect of instruction with graphing calculators on students' attitudes and ability to solve algebraic problems. Students in the experimental and control groups were given surveys to assess their attitudes towards mathematics and calculator use. Merriweather and Tharp found students were able to solve problems with the calculator that they could not previously solve, saw the usefulness of mathematics, and were more excited and involved in their learning. Through their review of research studies, Dunham and Dick (1994) also suggested students had more flexible approaches to problem solving, and were more willing to engage in problem solving and stay with it longer when calculators were available.

Graphing technology also allows for the examination of multiple representations, and mathematical modeling using real data is possible due to the availability of these calculators. Chandler (as cited in Merriweather & Tharp, 1999) found support for the position that there is a positive increase in understanding and achievement when students are able to visualize their work. Kastberg and Leatham (2005) maintain graphing calculators allow students to explore problems using graphical, numerical, and symbolic strategies and make links between these strategies. Dunham (1993) concurs that these calculators lead to a better understanding of the connections among different representations. In addition, students who use graphing technology are better able to read and interpret graphical information and relate graphs to their equations. The NCTM states that technology "enriches the range and quality of investigations by providing a means of viewing mathematical ideas from multiple perspectives" (NCTM, 2000, p. 25).

Graphing calculators can help students realize that mathematics has value. Instead of solving contrived problems, students can be given more interesting problems using real-world data. Calculators simplify tasks but they do not do the real work. It is up to the student to read the problem, understand what is being asked, determine the appropriate approach to use to solve the problem, and interpret the solution to determine if it makes sense. Graphing calculator technology should be used to enhance the study of mathematics and foster basic understanding, not replace it. Calculators are learning tools, not computational crutches, that permit worthwhile explorations of mathematics.

Presentation Software

The use of presentation software, such as PowerPoint, can provide structure to a lecture and aid in pacing and summarizing material presented. Yet, there is some debate about the benefits of using this type of presentation software in the classroom (Levasseur & Sawyer, 2006; Sugahara & Boland, 2006). Research regarding the impact of the program on academic achievement is mixed and research on using PowerPoint in mathematics is scarce. However, many research studies have shown that using presentation software effectively could be beneficial to students (Apperson, 2000; Susskind, 2005; Clark, 2008).

Research suggests that purposeful and well-designed use of presentation software can enhance student learning since it can allow teachers to vary their method of delivery and appeal to students with a variety of learning styles. In a qualitative study, Clark (2008) surveyed 46 college students to explore the impact of the use of PowerPoint in lectures and found that students preferred PowerPoint when used as a tool in the lecture. Of the students surveyed, 89.13% indicated they believed PowerPoint enhanced their learning. Clark stated that students indicated the visual stimuli provided in a PowerPoint presentation helped to gain and maintain their attention. She also noted that students viewed the use of presentation software as effective only when it was well-designed and used by an interesting presenter.

Pearson, Folske, Paulson, and Burggraf (1994) conducted a two year study of 168 students enrolled in a course that used computer-assisted multimedia presentations. Their research indicated knowledge retention of material by students was greater with the use of presentation software than in traditional lecture classes. Additionally, 94% of the students reported they enjoyed the course and two-thirds reported they learned more when PowerPoint was used. Szabo and Hastings (2000) reported on earlier studies using PowerPoint during lectures and the findings suggested the presentation software would increase students' grades, improve class attendance, and reduce some disruptive behaviors during lectures. In their quantitative study of 155 students, Szabo and Hastings found students preferred PowerPoint lectures but the use of the presentation software did not lead to better academic performance. They did find PowerPoint lectures might benefit memory retention better than traditional lectures. Apperson, Laws, and Scepansky (2006) echo the findings of Szabo and Hastings in that there were no significant differences in grades but students believed PowerPoint facilitated their learning. Investigating the benefits and effectiveness of instructional technology, data was collected from five faculty members and from students enrolled in ten different classes across two semesters. Apperson et al. surmised that using PowerPoint made for a better class experience for students from their point of view.

While student engagement is increased with focus, instructors should be sure to design presentation software slides in a manner that allows them to communicate concepts and engage students in the material being taught (Clark, 2008; Stryker, 2010). Students need to realize they cannot understand mathematics by observation alone; therefore, how the slides are designed and how much information they contain is critical when incorporating them into the lecture (Stryker, 2010). Mathematical content and pedagogy should not be compromised. Discussing the use of presentation software in mathematics, Stryker suggests creating slides with a minimal amount of information that allow the lecturer to control the technology and create an interactive learning opportunity.

When teaching mathematics, it may seem difficult to incorporate presentation software. However, it can be done in a variety of ways. For example an instructor can use presentation software to create slides to publish for class notes or handouts to facilitate studying outside of the classroom. In the classroom, presentation software can be used to enhance a lecture when used to introduce or explore concepts or to provide creative opportunities to review material before exams.

Proponents of using PowerPoint in class believe it improves learning through enhanced attention and improves

recall of material presented. Merely replacing traditional lecture with PowerPoint does not improve academic performance, but it is an efficient ancillary that can improve learning. Much of the research indicates students prefer it and feel they do better in classes that make use of the software. Clearly, the research suggests that, as with the graphing calculator, presentation software should be used as a tool and not as that which drives a lecture. As with any technology, it should not be used in ways that can distract from the underlying mathematics.

Computer/Web-Based Instruction and Practice

Numerous studies have shown that computer technology, such as software and computer-based instruction, has a positive impact on and assists students in learning mathematics concepts. When used purposefully, computers can be important tools for improving student proficiency in mathematics and can enhance student outcomes (Wenglinsky, 1998; Souter, 2001). King (1997) performed a meta-analysis of 30 studies published from 1986 to 1995 to investigate the effect of computer-enhanced instruction on college level mathematics and student achievement. His results showed there was a positive influence on student achievement when computers were used either in the classroom or a lab setting and when students were allowed to use technology while testing. King also found that using computers in instruction, including for demonstrations, was most beneficial.

Kulik and Kulik's (1991) meta-analysis of findings from 254 controlled evaluation studies that compared student learning in classes taught with and without computer-based instruction showed that computer-based instruction had positive effects on student exam scores and attitudes. In Kulik's (2003) review of literature, five of six evaluation studies comparing a computer tutoring group with a control group found the effects of the computer tutoring was "statistically significant and educationally meaningful" (p. 59). Other studies have shown that students who use computer-based instruction or web-based practice find doing math more enjoyable, participate more in class, and have less anxiety concerning mathematics.

Nguyen and Kulm's (2005) quantitative study on web-based instruction involved two different middle schools in southeast Texas with 95 students from six mathematics classes. Students were randomly assigned to an experimental group using web-based instruction and practice and a control group that did paper and pencil practice. Nguyen and Kulm's results revealed that students who used a web-based approach to instruction had significantly higher mathematics achievement on posttests than those using paper and pencil approaches. Their results indicate web-based practice and instruction can improve student learning, aid in self-motivation in learning math and in problem solving, and allow students to have independent practice. Student evaluation of web-based practice shows they are willing to spend the time it takes to improve their scores and gain better understandings of the mathematical knowledge required to solve problems (Nguyen & Kulm, 2005).

Hodge, Richardson, and York (2009) investigated the effects of using a web-based homework tool on student motivation and perceptions of learning in a college algebra course. Their quantitative study collected survey data from 1394 students. They found students felt the web-based homework increased their mathematical understanding more than conventional paper and pencil work. Their results also suggest students were motivated to complete more homework possibly due to the immediate feedback they receive (Hodge, Richardson, & York, 2009). Mavrikis and Maciocia (2003) discovered that immediate feedback is one of the most important issues in web-based practice. Immediate feedback encourages low-achieving students to practice more and builds confidence in students unsure about their understandings of mathematical concepts and procedures. Additionally, students are able to master material by correcting their own mistakes.

Web-based courseware can be used to provide tutorials and practice with immediate feedback, teach and reinforce concepts, review, and check solutions. Speckler (2007, 2008) states web-based courseware improves students' success rates including higher levels of success in subsequent mathematics courses. Furthermore, using web-based courseware for practice and instruction motivates students to do more homework, engages students in active learning, and improves retention rates. White's (2006) study examined final exam scores of students in a finite mathematics course who used web-based courseware with those who did not, and found significant differences in performance between the two groups. The sample for her quantitative study consisted of 193 students from three of sixteen centers at a Florida college during fall 2004 and spring 2005 semesters. White's results found the final exam scores for those using the online courseware were significantly higher than those not using the courseware.

Technology alone will not improve instruction, but web-based instruction and practice have been shown to motivate students to complete homework leading to mastery of mathematical concepts. Using web-based homework tools provides instant feedback to students regarding the correctness of their work, while allowing them to rectify their mistakes.

Conclusion

Technology affects mathematics and teachers in many ways. According to Quesada (1996), technology is "forcing us to reevaluate not only what topics we teach, but also in what order we teach them, and what approach we follow while introducing a topic" (p. 162). Ellington (2003) concurs, stating "technology and the pedagogical changes resulting from it have a decisive impact on what is included in the mathematics curriculum" (p. 433). This sentiment is also reflected by the NCTM in the Principles and Standards for School Mathematics. How mathematics is taught and learned as well as what math is taught and

when are now being influenced by technology (NCTM, 2000). Therefore, educators need to consider how technology will affect what mathematics will be taught.

Many teachers find it challenging to incorporate technology into their courses and some are still reluctant to even use it. The reluctance to let students use technology as a mathematical tool promotes inequities that can affect them throughout their mathematical careers. While effective use of technology can improve student learning and teaching, just having the technology available does not automatically mean better instructional outcomes. Teachers need to decide what, how, when, and where technology will be used, and if it will enhance or hinder student understandings. Additionally, teachers need to be provided with opportunities to become knowledgeable regarding the various technologies that are available and to dispel any misconceptions or doubts regarding the use of technology. They need to learn not only how to use the technology, but also why its use is important.

The incorporation of technology often provides opportunities to engage all learners, and its potential in the teaching and learning of mathematics is unlimited. The appropriate use of technology will get more students thinking and reasoning mathematically (Pomerantz, 1997). But, technology in and of itself is not a panacea that will resolve all students struggles. Technology, in any form, is a tool for achieving instructional goals. As with any teaching tool, it can be used effectively or poorly.

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