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Abstract

The claim has long been made that the inclusion of technology in the high school mathematics classroom will improve student achievement. Guiding this paper is the question: What are the characteristics of the effective use of technology in the high school mathematics classroom? The analysis of literature will show that effective technology use often improves student learning primarily through increased motivation. Thorough questioning must take place before new technologies are brought into the classroom, including whether the teacher is equipped with the necessary skills and knowledge to successfully teach with the new technology. Lack of resources, primarily in the mode of funds, remains the most common barrier to the implementation of new technologies in high school today.
Chapter I: Introduction

Efforts at improving student achievement have been in place in the United States over the last several decades. These efforts have often been mandates handed down from state or federal governments and imposed on school systems in the form of curricular standards by which we all might find success in educating the nation’s youth. Governments primarily look at the school system when trying to make improvements but rarely view the individual learners.

The focus will be on the individual and on the problem of student motivation in relation to learning and achieving in the high school setting. In particular, the mathematics classroom, one of the historically most hated and feared of all subjects, shall be the focus with emphasis on the impact technology has on students’ learning, motivation, and achievement. For the purpose of this paper, ‘technology’ will refer to calculators, computers, internet, computer-based programs, electronic data collection devices, and portable devices such as cell phones and electronic readers. Current arguments hold that technology in the classroom is only helping to widen the achievement gap between the “haves” and the “have not's”. The opposition would insist that students of the 21st century simply cannot succeed without technology in the classroom. The impact of technology on students' motivation and learning may well be the answer to many of the deficiencies in our nation’s education system

Technology does have an impact on all of our lives, especially the youngest generations. None can deny that this impact is very pervasive in the educational setting of our public schools throughout the nation. Rapidly evolving, ever changing- technology has permeated every aspect of our lives, yet it remains somewhat of an anomaly in the classroom. Schools are mandated to include technology in the curriculum. Building leaders often rely on the classroom teacher to implement technology in the hopes that it is done correctly but with little actual training or
research. Teachers then are left to decide how, when, and why to use what type of technology to best get their lesson across to the pupils.

Statement of Problem

As technology advances and as state and federal governments increase their influence in the development of statewide and even nationwide standards of education, teachers are compelled to integrate technology into their everyday curricula. Often the demand is either imposed or at least implied and teachers are left to their will to integrate as they see fit. Little is done in the way of teacher training on the new technology and many teachers consider themselves ill adept in the self-training of new technology as would seem to be the norm for implementation (Pierce & Ball, 2009; Ruthven et al., 2009).

Technology is so influential in our society that it seems to be afforded the unalienable right to integration into the time-tested American education system without as much as a second thought. Individual districts devote huge portions of badly needs funds to technology (Hew & Brush, 2007) simply so they can ‘keep up with the times’ while little or no effort is given to teacher training (Hew & Brush, 2007; Pierce & Ball, 2009; Ruthven et al., 2009). The results are schools with huge amounts of technology that no one knows how to use. Further, it is the apparent assumption that technology must be a tremendous teaching tool, yet its effectiveness at improving learning in the classroom is unproven. Surprisingly, little research has been done in this area, leading to the development of this review.

Other relevant topics to the subject that arise from research are: the effect of technology on student motivation and standardized test scores, the implications of technology in the classroom for teachers, teacher reactions to the demands of technology use, and barriers to implementation of such technologies in the classroom. The mathematics classroom was chosen
to narrow the range of topics due to its close connection to technology. Arguably, the mathematics classroom should be the easiest place to integrate and implement technology in education.

In the year 2000, U.S. Secretary of Education Richard Riley released a report outlining five new national educational technology goals. They are:

(a) All students and teachers will have access to information technology in their classrooms, schools, communities, and homes; (b) All teachers will use technology effectively to help students achieve high academic standards; (c) All students will have technology and information literacy skills; (d) Research and evaluations will improve the next generation of technology applications for teaching and learning; and (e) Digital content and networked applications will transform teaching and learning (USDOE, 2000) (Irving & Bell, 2004, p.255).

As is most often the case with mandated goals, they are laid out before the schools to interpret and implement as deemed most fitting by the board of education and the administration. With these goals in mind, questions arise- leading to the development of the main focus of this review.

**Research Question**

*What are the characteristics of effective and efficient use of technology in the high school mathematics classroom?*
Chapter II: Review of Literature

The Effect of Technology in the Classroom

Perhaps no new advent has had, and will continue to have, such a profound effect in education and in the high school classroom as computer-based technology. Since the invention of the computer, man has debated the potential uses for it nowhere more than in education. The use of technology in the classroom has long been approved and recommended on all levels with an apparent lack of support from research. Why is this? This review will attempt to uncover some of the issues surrounding technology and its impact on student learning, student motivation, standardized test scores, and teaching in general while also giving voice to the contradictors and opponents to the uninhibited use of technology in the high school classroom.

"The belief that technology can positively impact student learning has led many governments to create programs for the integration of technology in their schools. In the United States, school districts reportedly spent $7.87 billion on technology equipment during the 2003-2004 school year” (Hew & Brush, 2007, p.224).

Student learning.

Numerous researchers indicate that technology does increase student learning (Hannafin & Foshay, 2008; Ornstein, 1995; Owens & Waxman, 1995; Reid-Griffin & Carter, 2004; Ruthven et al., 2009). Whether it is by increasing student motivation, increasing self-perception of learning and ability, or simply through making learning more fun, Hannafin and Foshay (2008) concluded that technology does increase student learning. In a quantitative case study of one Massachusetts High School's remediation program aimed at increasing passing rates on the state's year end competency exam in mathematics, Hannafin and Foshay examined test scores of tenth graders who were deemed at risk of failure based on previous eighth grade test results and
were therefore placed in a computer-based instructional (CBI) program in their sophomore year. An analysis of variance of the increase in test scores was conducted between those remediated and those not. The number of students studied was 126 (87 enrolled in the CBI program (treatment group) and 39 not (control group)). Hannafin and Foshay showed that the remediation group's improvement was greater than that of their counterparts enrolled in regular math education.

Though they acknowledged there could be other factors that attributed to the students’ increase in test scores, Hannafin and Foshay concluded that, even though the subjects were already identified as failures based on prior testing, the computer-based instruction did help them pass the state test. Additional outcomes were increased student motivation and positive student attitudes at experiencing success.

In a classroom experiment integrating internet use in the teaching of mathematics, Day (1998) reported findings on the impact of technology on student learning. Day asks three questions in his experiment: 1. *Can the web provide students a viable way to access course materials, information, and activities?* 2. *What investments of time and expertise are required to deliver web-based course materials?* 3. *What potential is there for the Internet to positively impact teaching and learning of mathematics?*

Day used his own classroom in several different courses over time to access student feedback in the form of written reactions in relation to his questions. Data was collected from student response to course evaluations at the end of the semester and was analyzed by simple summative techniques (i.e. 16 of 20 students access the web site at least once a week). Day indicated that students supported the use of web materials and technology in the classroom. Day found that the impact of technology on student learning is relevant through an increased time
spent by students outside of the classroom through and with technology. The web extended learning time by allowing students to continue on their own outside of the classroom. Though no bias is reported, Day reflected on his practices while considering possible issues such as, Would students benefit more from a redirection of effort and resources?

National survey data from 15,000 tenth graders regarding technology use in the mathematics and science classroom was analyzed by Owens and Waxman (1995). The purpose of the investigative study was to address the danger of inequitably distributed technology across the urban, suburban, and rural school systems. Owens and Waxman found that calculators and computers did improve student learning, and that the dissemination of technology was not inequitable as many would presume. Data were collected from National Educational Longitudinal Study student surveys. Specifically, responses to six questions relating to technology use were analyzed and summarized categorically. Chi-square tables were used to indicate differences amongst responses.

Despite the report that technology does increase student learning, the conclusions of Owens and Waxman were that technology is not widely used in the high school mathematics classroom. Though calculators were reported to be used about one-third of the time in the math classroom, computer use was much lower, indicating that we need to do a better job of including technology in the mathematics classroom.

**Student motivation.**

For most high school teachers, individual student motivation is one of the largest obstacles to overcome in the classroom (Pierce & Ball, 2009; Ruthven et al., 2009; Silver et al., 2009). Typical teen-age students of the twenty-first century are, as with any generation, much different than their parents. Today’s fast paced, technological world offers more distractions to
this next generation (or as they have come to be known…Net generation) than any before.

Placing those distractions on top of the already well-documented list of teen-age pressures, today's teen has a difficult task of staying on task when in the classroom.

Numerous authors, educators, businessmen, and politicians have, in recent years, been calling for a major reform of public education in the United States. These outcries are not uncommon throughout the history of public education in America; they are becoming more frequent and gaining popularity in current times. Themes of frequent attacks on education are as varied as the authors who create them. Central common points are few, but agree America needs to do a better job of educating her youth.

The advance of technology over the last decades has had no greater influence over any group as the youth of America (Hemenway, 2000). Statistics reporting the amount of time that teens voluntarily spend using technology vary greatly except in that, they are all astoundingly high numbers. It is only natural that using this new and exciting format for teaching should motivate students to be more interested and active in the process of learning.

It may be that, of all the benefits to using technology in the classroom, increased student motivation is the greatest. Hannafin and Foshay (2006) reported that students involved in technology based instruction not only experience greater achievement, but also show greater interest in subjects areas, have more favorable attitudes toward learning, and increased motivation in addition to, overwhelmingly favoring computer based learning (97%).

In an investigation of theories on motivation and learning, Ornstein (1995) provides us with twelve basic applications of these theories for producing learner success.

1. Be sure students can fulfill their basic school needs.

2. Make sure the classroom is comfortable, orderly and pleasant.
3. Help students perceive classroom tasks as valuable.
4. Be sure tasks are suitable for students’ capabilities.
5. Recognize that students have different levels of anxieties and need for advancement.
6. Help students take appropriate responsibility for their successes and failures.
7. Help students set reasonable goals.
8. Provide variety in learning activities.
9. Use novel and interactive instructional methods.
10. Use cooperative learning methods.
11. Monitor students’ work; provide feedback.

Ornstein derived the list from his review of several theories of motivating behaviors, largely from cognitive psychology. No data collection or analysis was done in the study. With the exception of only a few of the most basic motivators, it is clear that the use of technology would be able to help teachers in all fields achieve these desired outcomes, thereby improving student learning for all students in the classroom.

General agreements on the effectiveness of technology as a motivator are that technology does foster a greater interest in subject matter, and that technology can be applied to all classrooms, not just that of mathematics and the sciences (Day, 1998; Ornstein, 1995; Pierce & Ball, 2009). An unexpected generality amongst sources was that the increased use of technology also fostered an increase in parent communication and involvement (Hew & Brush, 2007). Sources agree that technology does lead to an increase in student-centered learning (Hew & Brush, 2007; Pierce & Ball 2009). The negative reports of technology are few but profound. The biggest downfall is the fact that technology was expensive to acquire and maintain (Hew &
Brush, 2007; Owens & Waxman, 1995). There is no end to the dilemma of funding in American Education and lack of funding leads directly to a lack of technology in schools. Other negatives such as teacher training and technological support can also be tied directly to funding (Hew & Brush, 2007). Further discussion of these issues will ensue in the following section; Barriers to Technology Implementation.

**High-stakes tests/standardized test scores.**

Often mistakenly overlooked in the argument over technology use in the classroom is one of the biggest drivers of curriculum development itself, the high-stakes test. Whether it be a state administered test (in some places mandatory passing is required for graduation), or the common college entrance exams (ACT/SAT), or any other variety of examination which has tied to it funding, scholarship dollars for students, school report cards, or teacher evaluation criteria; these high-stakes tests drive more and more of what we do in the classroom (Hannafin & Foshay, 2006; Irving & Bell, 2004; Judson & Nishimori, 2005). Hannafin and Foshay (2006) argued that though we agree that computer based instruction is important and helpful in today's classroom; teachers and schools are often forced to push aside technology in the time crunch that is-getting students prepared for high-stakes tests. The aptly named 'high-stakes' tests are of such importance to both the individual and the school that taking the time to include technology in the curriculum is not worth the risk of not covering the curricular standards.

In a close look at National Standards and national education testing programs, Irving and Bell provided a necessary (and distinctly opposite) insight into the nature of technology in the classroom by asking the question, “Do commonly used national assessments support the vision of technology use provided in the standards? In other words, are national standards and assessments providing a vision for teachers that will guide them to prepare their students for a
technology-rich future?” (Irving & Bell, 2004, p.256). Irving and Bell analyzed such documents has the Standards2000 published by the National Council of Teachers of Mathematics (NCTM), the National Science Education Standards published by the National Research Council (NRC), and the National Educational Technology Standards (NETS) produced by the International Society for Technology in Education (ISTE), and found that at least in the area of mathematics, they provided the correct foundation and vision of technology to be followed in the classroom.

Methodology used by Irving and Bell was to probe all of the aforementioned documents for explicit reference to technology use in education. Each was assessed for number of references and of what type and then a cross comparison was evaluated. “If teachers truly teach to the test, then these national standardized tests provide high motivation for mathematics teachers to include electronic calculators as part of their classroom teaching,” (Irving & Bell, 2004, p. 265).

Teaching.

The impact of technology implementation on the classroom teacher is arguably greater than that of even the student. The teacher is most often the deciding factor of exactly what technology will be used and what will not. It is ultimately the teacher’s decision to decide what technology will most benefit student understanding of mathematics and at the same time improve test scores. Often the issue is that of time; both in teacher preparedness and knowledge, and the time it takes the students to learn the necessary new technologies to the point of benefitting from them. Unfortunately, the final decision is often answered by the affordability of such technology.

In a report on teacher perceptions towards using technology in the high school mathematics classroom, Pierce and Ball (2009) analyzed 92 different secondary math teachers' responses to a voluntary, state wide survey in Australia. The purpose was to understand teachers' perceptions
as to the enablers and barriers to technology use in the high school math classroom. Data was collected by Pierce and Ball via emailed surveys. Teacher demographics were considered to be diverse. It is important to note that the system in which these teachers worked had an, "expectation that technology is incorporated in teaching and learning and used by students in assessment" (Pierce & Ball, 2009, p.314). One could argue that our perception in the United States is the same with the exception of using technology on many high-stakes assessments.

The results Pierce and Ball found compare closely with reports in the United States. Teachers overwhelmingly agreed that the use of technology would help motivate students, connect them with more real world problems, make math more fun, and deepen students' understanding of math. Teachers also felt that cost was prohibitive (both for the schools and for individual students), and that learning new technology meant a large devotion of individual teachers' personal time and effort. More concern was given to the fear of not having time to cover course content if too much time was spent on integrating technology. Pierce and Ball concluded that individual teacher perceptions are mixed as to the value of technology and that more needs to be done in the way of teacher preparedness to use technology effectively in the classroom.

**Contradictions.**

Hannain and Foshay (2006) noted that while introducing technology into the classroom may appear to result in an increase in student achievement, the result could otherwise be attributed to such factors as; teacher input, the introduction of a new medium itself that is exciting for a while but will then diminish, increase in student self-perception, attitude towards learning, and motivation or interest that is caused by the technology. The argument is that the technology is not the root cause of the increase in student achievement, but rather caused
increases in other areas that in turn increased achievement. That is to say, a field trip might cause the same increase in interest and therefore in achievement.

One of the great historical arguments against technology has been that it will always be inequitably distributed between the rich and the poor, between the rural, urbanites, and the suburbanites. If this were true, then technology would most certainly cause a widening gap in achievement amongst these demographics. Owens and Waxman (1995) showed that based on nationwide survey data, technology is more equitable than many of us might have assumed. Owens and Waxman found that rural students use computers more in math than urban and suburban students but the trend is opposite in science, where urban and suburban students use computers more than rural students. Owens and Waxman concluded that technology is available in nearly every school but it is considered to be poorly integrated into the curriculum and under-used.

The Effective Use of Technology in the Math Classroom

The most widely used and accepted form of technology in education is the Internet. Using the Internet as a teaching aide in classrooms has a direct impact on students’ motivation to learn. In an article focusing specifically on the impact of the Internet on learning, Hemenway (2000) conducted research on the matter by randomly surveying 150 California high schools as to the amount of internet use in the classroom. Follow up phone interviews were conducted with 25 teachers and the results were summarized. Hemenway quoted interviewed teachers explaining differences in the classroom since the adoption of Internet use; “students are highly, highly, highly engaged”, “they explore on their own, science is more fun for them”, “it has created an era of willingness to work”, “the students have increased analytical skills in the depth of their searches”, “the learning rate is much more accelerated”. “Many issues need to be refined
before the Internet becomes a transparent tool of the new millennium, but its availability as a tool is moving the role of the teacher along the path from the holder of information to the motivator and guide of student learning” (Hennenway, 2000, p.119). Education today is still witnessing the transformation to increased Internet use in the classroom.

Having computers available for students to use when and where needed is an important step in motivating students through technology. Several states have received funding for laptop initiatives, providing every student with their very own personal computer. These initiatives have affected student motivation and learning in an extremely positive manner. O’Hanlon (2007) reported upon a 1-to-1 laptop initiative began in Texas in 2004. Upon evaluation of the program in Texas, school leaders said, “Anecdotal success—accounts of positive transformations in the classroom from students, teachers, administrators, and parents—only serves to bolster the formal evaluations of these programs” (O’Hanlon, 2007, p.26). A similar program in Maine lead to the statement:

There is a growing body of evidence that Maine’s Learning Technology Initiative is impacting teachers, students, and learning in many positive ways: *Teachers are more effectively helping children achieve Maine’s state learning standards *Students are more motivated to learn, are learning more, and learning it more deeply *Students are acquiring 21st-century skills *The 1-to-1 laptop program is bringing about positive change in the acquisition of knowledge. (O’Hanlon, 2007, p.26-27).

Hew and Brush (2007) recommended several general practices in order to overcome typical barriers to more effectively integrate technology into the general classroom. To provide more one to one student to computer access, mobile laptop carts are suggested in order to alleviate the issue of sharing one computer lab. Further, mobile labs save schools the costs of building and
maintaining permanent computer labs. Placing several computers in each classroom is another option that increased technology use. Hew and Brush found that teachers who had five or more computers in their classroom incorporated them in the curriculum twice as often as those who did not. If teacher class loads can be reduced, this would allow them time to further their technological skills and increase technology usage. Similarly, content can be reduced to free up teacher training time on technology. Teachers who collaborated to create technology based lessons find more time than when working alone. Focusing on teacher-centered technology-based professional development was a key feature of effective technology use in the classroom.

A qualitative research design case study by Reid-Griffin and Carter (2004) addressed one of the root problems with technology implementation: how to implement technology effectively. There are endless accounts of the praises of technology in the classroom and the effect that technology can have on student learning yet; there is little information on how exactly to incorporate such technology. Reid-Griffin and Carter warned of the adoption of technology and the potential negative aspects of not using it correctly. Instead, the idea is offered, that instruction can be restructured to allow for the effective adoption of technology into the lesson.

In the study, Reid-Griffin and Carter suggested scaffolding as a model of instruction to allow for the full and effective use of technology integration and exploration in the classroom. Though seventh and eighth graders were used in the study (n=23), where the current review has focused primarily on high school age students, the participants were from a gifted and talented magnet school and considered to be advanced in mathematics, thereby enrolling in high school mathematics classes up to the level of geometry. Students were observed via a single case study design in an elective class ‘Exploring Technologies’ and student interviews were conducted in addition to audio and video observation, examination of student notebooks and journals, and
regular classroom observations. “Students’ perceptions of technologies as tools developed gradually in the course of the study. Students were able to offer complete explanations of their findings during small group and whole group discussions. They were able to use data collected to develop their own understanding of scientific phenomena.” (Reid-Griffin & Carter, 2004, p. 503). The conclusion of Reid-Griffin and Carter was that the scaffolding model does allow for the effective infusion of technology into the curriculum.

In a case study of the use of graphing software in the secondary mathematics classroom in England, Ruthven, Deaney, and Hennessy (2009) recommend a practitioner model for the successful contribution of technology to teaching mathematics. In the study, Ruthven et al. conducted group interviews with mathematics departments in addition to classroom examination of teaching practices. From the focus group two different cases were observed in different regions of the country. Qualitative data were recorded through observations of two lessons per teacher in the differing schools and from follow-up teacher interviews. The suggested model of Ruthven et al. was that technology contributes to the following,

- Effecting working processes and improving production
- Supporting processes of checking, trialing and refinement
- Overcoming pupil difficulties and building assurance
- Focusing on overarching issues and accentuating important features
- Enhancing the variety and appeal of classroom activity
- Fostering pupil independence and peer exchange

Ruthven et al. concluded that the teachers in the study did see graphing software as contributing to this model.
Linkenheimer (2005) suggested asking five specific questions of high school students before an attempt is made to implement technology in the math classroom and the high school curriculum as a whole. These five questions came from a Gallup Poll commissioned by the International Technology Education Association (ITEA) in 2001. Linkenheimer (2005, p. 6) chose these five questions based on their basic concepts about technology that students should know. They are:

1. When you hear the word “technology,” what first comes to mind?...computers, electronics, education, new inventions, internet, science, space, job work.  2. When you hear the word “design” in relation to technology, which one are more likely to think of—“a creative process for solving problems” or “blueprints and drawings from which you construct something?”  3. Which of the following statements best describes your attitude toward the various forms of technology you use in your everyday lives? A. You don’t care how it works as long as it works. B. You would like to know something about how it works. C. Don’t know/refused.  4. To which of the following do you feel technology is of the most importance and has the greatest effect?...Our society, Our environment, The individual, or Don’t know/refused.  5. If you believe that technology should be part of the curriculum, should the study of technology be made part of other subjects like science, math and social studies, or should it be taught as a separate subject?

Once the results of the survey were analyzed, Linkenheimer claimed the teacher can make adjustments and additions where necessary to improve instruction of and with technology.

Another research study conducted by Alagic and Alagic (2013), questioned whether the formal structure of the traditional classroom is at all conducive to the implementation of technology in the learning of mathematics. The argument was made by Alagic and Alagic that
collaborative learning of mathematics in the online environment is superior to the traditional instructor-student model. In the study of many various online math forums, websites and projects, Alagic and Alagic concluded that there are tremendous opportunities in collaborative online learning of mathematics that are otherwise impossible in the traditional classroom setting with a single teacher.

In a four-year-long research study of the program SimCalc and its intervention into the high school math curriculum in Algebra I and II in Southeastern Massachusetts, Tapper (2013) reported on the findings from multiple interviews of 18 teachers regarding the program. Analyses of phenomenographic data were summarized in yearly reports using a constant comparison method to create a unified theory. Tapper concluded that, though teachers did believe the use of SimCalc changed their views of instruction and pedagogy in addition to deepening student understanding of mathematics, teachers were overwhelmingly opposed to full adoption of the program as the primary means of learning math. Reasoning included the unanimous belief that SimCalc was not for everyone, concern for how its students would perform on high-stakes tests, and departmental restrictions. “The evidence of teachers’ experience with SimCalc led most of them to the conclusion that many of their students were too steeped in traditional pedagogy to benefit from an inquiry approach to math learning, and/or had a disposition that would only allow them to learn mathematics if it were first demonstrated to them” (Tapper, 2013, p. 282). In addition, Tapper found that the implementation of SimCalc curricula was demanding on teachers through increased preparation, difficulty with inclusion of diverse students, and changing past tendencies to control the classroom structure and flow.

**Barriers to Technology Implementation**
In order to answer the question of why more technology is not being incorporated into the classroom we focus on the barriers to implementing such technology. Hew and Brush (2007) performed a research study in which were identified the common barriers. From a total of 123 different barriers, six categories, in order of frequency of occurrence, were formed as follows: 1. resources, 2. knowledge and skills, 3. institution, 4. attitudes and beliefs, 5. assessment, 6. subject culture. Empirical studies throughout the world were sought out and from 48 studies the constant comparative method of data analysis was used to develop the categories. The results of Hew and Brush along with further review from other sources follow.

**Resources.**

The most frequent barrier to technology use is available resources. According to Hew and Brush (2007), lacking of resources most often includes technology, access to technology, time, and technical support. It is common to find available technology in schools where access to that technology is not readily available. Often, technology is housed in a computer lab where teachers must 'compete' for access and only one class may utilize the lab at any given time. Hours of time are needed by teachers to find and preview web sites and prepare technology enhanced lessons, Hew and Brush reported, and "teachers who were willing to work longer hours paid a personal price in "burn out", and an eventual exit from the school" (p.227). Technical support for teachers is reported as often being inadequate.

**Knowledge and skills.**

Hew and Brush (2007) point to the lack of specific technology knowledge and skills as one of the most common reasons given by teachers for not using technology. Technology supported pedagogical knowledge and skills and technology related classroom management are among the other barriers to implementation. These support the claim that though schools often have the
technology, they are not allowing teachers to use it properly through lack of training on the specific technology and lack of pedagogical development using technology.

Pierce and Ball (2009) refer to this myriad of; technology knowledge and skills, technology supported pedagogical knowledge and skills, and technology related classroom management knowledge and skills…collectively as technological pedagogical content knowledge (TPCK). Pierce and Ball found that teachers lacking in TPCK are less likely to use technology in the math classroom. Teachers cited fear that it would take up too much of their personal time and that they would not have time to finish the coursework if they had to implement technology on a regular basis.

In an analysis of portfolio entries for National Board for Professional Teaching Standards (NBPTS) certification; Silver, Mesa, Morris, Star, and Benken (2009) provided further insight into the deficiency of TPCK amongst teachers. With the call for improving math teaching and learning in America, an attempt was made by Silver et al. to uncover and understand what it is that teachers do to improve mathematics instruction in the classroom. A concern for teaching mathematics for understanding was addressed by the group, a part of which implied the use of technology.

From 250 applicants to the NBPTS certification in 1999, Silver et al selected 32 in a random sample for further study. These samples were analyzed both qualitatively and quantitatively for evidence of pedagogy including the use of technology. Silver et al. reported that in 59% of the sample portfolios teachers were using technology as compared to only about 49% who reportedly use technology on a nationwide survey. Though this number is higher than the national average, one can assume that amongst the 'best of the best' teachers, as those who would apply for the prestigious NBPTS certification, one should see close to 100% of applicants
using technology in submissions of this nature. A more troubling find by Silver et al. was the lack of high demand cognitive tasks necessary for teaching math for understanding.

**Institution.**

Institutional barriers to technology implementation found by Hew and Brush (2007) include leadership, school time-tabling structure, and school planning. They found that the common class structure of an hour or less limits the amount of technology a teacher can include in any daily lesson. As a result, teachers do not plan to use technology on a regular basis. Hew and Brush further concluded that administrators who do not place importance on the use of technology in the classroom impede teachers from implementing technology.

**Attitudes and beliefs.**

"The decision of whether and how to use technology for instruction ultimately depends on the teachers themselves and the beliefs they hold about technology." (Hew and Brush, 2007, p. 229). It is commonly felt that teachers who were taught themselves without the use of technology do not see the importance of it now in teaching. "Teaching mathematics with technology requires a marked change in behavior for practis(c)ing mathematics teachers who have taught, and been taught, in traditional mathematics classrooms dominated by working with pen and paper" (Pierce & Ball, 2009, p. 300).

**Assessment.**

A direct contradiction between the use of technology and assessments was brought to light by Hew and Brush (2007) when they noted that many high-stakes assessments do not allow for the use of technology. This was a concern to teachers resulting in their limiting or even prohibiting the use of graphing calculators in the math classroom, fearing the students' dependency on such may lower test scores where they are not allowed the technology. In this
light, the assessment, in and of itself, is determining the technology allowed to be used in the teaching of the subject of mathematics.

Agreement on the matter comes from Pierce and Ball (2009) in their conclusion that the negative impact of such 'external constraints' as the non-allowance of a calculator on a high-stakes math test would impede a teacher from using that technology in the classroom.

Additional insight into the nature of assessment comes from a study of two above-average high school calculus classes, one in the United States and one in Japan. Judson and Nishimori (2005) examined and interviewed 18 Calculus BC students here in the States and compared them to 26 advanced Calculus students in Japan. The purpose of the study was to investigate differences in high school students’ understanding of Calculus here versus over-seas. Student from both countries were given two written examinations after which, individual interviews were conducted. Mean scores were tabulated and box and whisker plots were used to compare the distribution of scores between the two groups. Judson and Nishimori found little difference between the conceptual understanding of calculus but did note that the Japanese students did display a greater understanding of algebraic skills during the examinations. The pair also concluded that many of the American students did rely on the calculator as a problem solving tool.

One of the more interesting facets of this particular study was in the observance of the individual classroom from which each group came from. Judson and Nishimori commented that the teaching style in both American and Japanese advanced Calculus classrooms was teacher directed with a lecture based format. The Japanese students were not permitted to use scientific calculators and were quite unfamiliar with graphing calculators. The American counterparts only used graphing calculators out of necessity since they are required for the BC Calculus
Examination and the American teacher emphasized this was the only reason for their existence in the classroom.

Here, a critical understanding of technology use in the mathematics classroom comes to the foreground in the form of opposition to earlier studies where authors cite that calculator allowance on Standardized tests should cause teachers to use them more in the mathematics class. Judson and Nishimori showed exactly the opposite is happening in the most advanced math classes offered in high school in the United States and in Japan where teacher-centered learning is still the norm.

**Subject culture.**

The least frequent of all barriers to technology, though possibly the most intriguing, is the aspect of subject culture. Subject culture refers to the attitude surrounding a certain subject that has been formed over time, through practice, based on history, and generally accepted by most professionals of that subject (Hew & Brush, 2007). It is not uncommon, according to Hew and Brush, for a teacher to be unwilling to use technology based solely on the certain subject culture. For example, an English teacher might consider holding a book and turning the pages a part of the experience of reading that would be lost if that same story were being read off of a computer screen.
Chapter III: Results and Analysis

Results and Analysis of the Effect of Technology in the Classroom

Researchers generally agree that technology use in the mathematics classroom does have a positive impact on student learning (Day, 1998; Hannafin & Foshay, 2006; Owens & Waxman, 1995). Pinpointing the impact to an exact indicator is impossible due to the variety of technologies, the variety of ways those technologies are used, and to what extent the technology is implemented. Amongst the largest of indicators remains student motivation as the one universal positive outcome of technology. Through increased student motivation, researchers indicate, teachers typically experience positive outcomes due to technology use and a resultant increase in student learning.

The impact that technology use in high school mathematics has on high-stakes tests seems to be still a matter of debate. Where the use of graphing calculators is permitted, suggestions are that their implementation into the curricula will result in an increase in student scores (Hannafin & Foshay, 2006; Irving & Bell, 2004). Generally speaking, technology use in other forms takes up valuable contact time and can result in decreased test scores through materials not covered (Pierce & Ball, 2009).

Technology use can result in an increase in student motivation, which causes increased learning, and thereby, higher test scores (O’Hanlon, 2007; Ornstein, 1995). The investment of time on the part of the teacher is often too great and one that cannot be justified. This may in part be due to lack of teacher training and funding, as well as a failure on the institutional level to commit to a unified technology plan (Hew & Brush, Pierce & Ball, 2009; 2007; Ruthven et al., 2009). The myriad of technological devices available contributed to an overwhelming decision
on the part of both teacher and school as to what kind, how much, and to what extent it is to be implemented.

Results and Analysis of the Effective Use of Technology in the Math Classroom

Common themes do emerge from research on the effective use of technology in the mathematics classroom. Most importantly, computer access is the key to implementation. Access must be fair and equitable, and available to all students. Most districts found this is accomplished through some form of laptop program, whether it is extensive, as in a 1-to-1 laptop program, or minimal and affordable, as in 'rolling labs'.

The greatest use of technology in today's classroom remains to be the internet and its ever-growing list of infusible applications into the curriculum. Specifics on individual technologies and available programs for mathematics applications are so varied that there remains no one universal program that is found to be of the greatest benefit. These individual programs remain left up to the user, the individual teacher and school to decide where and whether their application will be of benefit to the district and its students.

Results and Analysis of Barriers to Technology Implementation

Where there is endless disagreement on how to best incorporate technology into the math classroom, there is as much agreement on the barriers to the implementation of such technology. The greatest of these barriers fall into the categories of resources and teacher knowledge and skills (Hew & Brush, 2007; Pierce & Ball, 2009; Silver et al., 2009). Hew and Brush found that resources were the greatest barrier to technology implementation with teacher knowledge and skills being the second greatest reason for lack of technology use in the math classroom. Although the frequency of barriers due to resources was nearly double that of knowledge and skills, more studies seemed to focus on the issue of knowledge and skills. This may be due to
the relative helplessness of the individual when a lack of funding exists while solutions to the latter are more attainable for the individual, group or school.
Chapter IV: Conclusion

Recommendation

Implementation and successful use of technology in the mathematics classroom should be approached carefully and with much regard as to the intent and purpose of the technology. That is, one should ask the following questions: What is the primary purpose or driving force for the change or implementation? How will it be afforded? How much classroom time will be afforded this new implementation and what content will be eliminated as a result? How much time will the teacher need to become skillful enough to make the new technology a benefit to the students? What teacher training needs to take place to make the implementation successful? If all of these questions are answered and analyzed carefully before proceeding with a new implementation of technology, then its effective use in the mathematics classroom will occur to a higher degree of success of all constituents.

Specifically, computers should be made available to the greatest extent possible to each individual student based on the teachers’ and the districts’ desire for their implementation. Teacher training on computers and any new incorporated technology needs to be facilitated by the administration to a much higher degree than it has been in the past. Continued technological support and training needs to be a regular occurrence through professional development opportunities and should be mandated wherever technology is being incorporated. If a district places importance on the implementation of technology, then the administration needs to follow-up to see that technology is being used on a regular basis in the classroom. If the desired technology is not observed, the administration should find out why and provide the opportunity to help the teacher in incorporating it.

Areas for Further Research
Further research to address the question of the characteristics of effective and efficient use of technology in the mathematics classroom is needed in the area of teacher knowledge and skills surrounding technology. Cluster samples of high school mathematics teachers across varying geographic regions of the country should be surveyed through an online resource as to the extent of their technological abilities, current effective and efficient use of technology in the classroom, and willingness or ability to participate in further teacher training to effectively incorporate new technologies. Quantitative data should be gathered from the surveys and analyzed both wholly and using comparative methods across regions. In this way, we could gather a much greater insight into what effective technology looks like in the math classroom, which teachers are using it, and how it might be extended to others in order to improve the instruction and learning of mathematics in the high school classroom.

Conclusion

The characteristics of effective and efficient use of technology in the high school mathematics classroom are somewhat illusive still to the present day. It is largely concluded that technology use does improve student learning and test scores through increased motivation, but the type of and effective use of technology cannot be determined from current review. The variation in types of technology and methods of implementation prove too large a study for the present scope of this paper. Further research is needed in the area of teacher knowledge and skills surrounding technology. Issues surrounding school resources and teacher knowledge and skills remain as the greatest of barriers to technology implementation and effective use in the high school mathematics classroom.
References


