Student-Centered Learning and Technology: Keys to Successful Mathematics Instruction at the Middle School Level

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Abstract: This paper investigates the current problems and potential solutions in middle school mathematics classrooms. What are the problems, and what has technology done to alleviate some of the ongoing problems? Has technology helped, and if so, how? We look at a few computer aided technological solutions, studies done on those solutions, what the strengths and weaknesses were of the programs, and what this may mean for the future potential use of technology in mathematics classrooms. Beyond the need for technology integration, the claim made here is that specific changes, taking into account the behavioral nature of middle school aged students, must be implemented at an instructional design level first and foremost to significantly improve middle school mathematics education.

Introduction

When considering the integration of technology into mainstream mathematics classrooms, sixth grade through college, there has been some progress and some research on technological innovations and how they relate to teaching and learning, but there is much work to be done. Calculators are used at nearly all levels now, but unfortunately for some, "… the computer becomes a tool for developing drill and practice skills, a lower order cognitive skill." (Hardman, 2005; Clarke, 2005). On the other hand, calculators can take care of some of the tedious calculations and therefore free up time for deeper learning. This is particularly useful for high school age and above.

Other uses of technology in recent years include some use of computers to aid in the learning of Algebra and Geometry. Textbook companies have step-by-step answers to their exercises online. While this can be helpful, it can also give the student the false impression that there is only one way to solve some algebraic problems. Thus, it can be misused. There are online programs available that teach the entire course of Algebra and Geometry online for credit, although there is some debate about whether multiple choice testing really can take the place of written responses in mathematics. More promising are interactive software applets and games that better engaging students. Indeed, these innovations herald "… the introduction of the computer as a tool that can facilitate the development of creative, student-centered learning contexts capable of producing the kind of teachers and students demanded by OBE (Outcomes-Based Education)." (Hardman, 2005).

Another media used is the DVD. There are some great mathematics lectures available now on DVD. These lectures are not just people speaking, but also have graphics, demonstrations, and animations to help students understand deeper levels of mathematical concepts. In graduate education mathematics courses, software tools such as Matlab, MathCAD, Maple, as well as WebCt, can enhance the distance learning experience.

However, despite these advances, which are integrated more and more at post-secondary institutions, it is the rare mathematics teacher who incorporates technology into the middle school classroom, even occasionally. "Because few current teachers have experienced, or even observed, the use of technology in their own K-12 schooling, they are unlikely to have many preconceived ideas about how technology should be used to achieve student learning." (Ertmer, 2005). This can mean that these teachers aren't sure how to incorporate it effectively. And, "…whereas some teachers may think of technology as just another tool they can use to facilitate student learning, others may think of it as one more thing to do." (Ertmer, 2005).

So how as educators can we alleviate some of the problems? This paper investigates the use of mathematical software to engage, entertain, but most importantly to educate these students.

Problems

One of the biggest problems in the teaching of mathematics at the middle school levels is lack of motivation on the part of the students. It is difficult to keep the students interested enough in the material to learn it. They often don't see the relevance; they can be disruptive when unmotivated, making it difficult for others to learn. (Hannafin, 2004; Bjorklund, 2002). There is such a wide variety of abilities by the time one gets to sixth, seventh, and eighth grades; some students still have not yet mastered their multiplication tables or long division, some are simply at grade level, some are in Pre-Algebra, some are in yet higher mathematics such as Algebra and Geometry. For smaller school districts in particular to attempt to meet the needs of all of these levels is difficult at best.

By the time students reach high school, most have some reason in their minds that keep them somewhat interested in passing their math class. They need the subject to graduate, and if they have post secondary school plans, they need to do reasonably well. There are also state exit exams, and SAT or ACT tests. But in the middle grades, a lack of maturity makes such forward thinking vision impossible for most, and relevance is a key issue. They simply cannot connect with mathematics. Of course, the critical thinking skills and problem solving abilities that they are in the process of developing will have a life long component to it, but many of this age group cannot see that yet. Indeed, there is substantial evidence to suggest that developmentally these middle school aged students have an emotional immaturity that should not be dismissed, but actually can be worked with for the benefit of all. (Bjorklund, 2002).

For this younger age group, teacher centered teaching is a problem. In addition, teachers "cited failure on behalf of …[their former] teachers to make connections between topics that [they] knew to be very much related." (Beswick, 2007). Thus, they should have "stressed the importance of helping students to make links and emphasized the need to seize opportunities to teach from where the students are in terms of their understanding and interest." (Beswick, 2007). This is more of a constructivist viewpoint, and one this paper will reinforce as the primary change needed to help this age group.

Technology Uses – Strengths and Weaknesses

Technology has been used and studied, and the results are worthy of our attention, as the middle school age children need effective mathematics instruction now. While there have been several advances, such as the use of the calculator and software that comes with specific textbooks, these advances do not engage the student in a vibrant way. So, specifically, we looked at three types of computer technology created with the intention of teaching mathematics to middle school students. They are applets, computer software designed to enhance specific topics, Geometry sketchpad, aimed to help students discover and visualize their work, and Math Insight software, designed again to help students create meaning.

Applets

The applets were small software "games" that are interactive and teach specific topics to the middle school grades. They were found to be largely entertaining, engaging, and educational. In fact, "findings from Renninger et al.'s (2003) study of student work with the EpoWs [Problem of the Week] suggests that these software-enhanced problems were motivating for students." (Underwood, 2005).

Indeed, students who are presented with alternate ways to view concepts have a better chance at understanding complex concepts. "The design of technology tools has the potential to dramatically influence how students interact with tools, and these interactions in turn may influence students' content area understanding and problem solving." (Underwood, 2005).

Geometry Sketchpad
Geometry Sketchpad software asked the students specific questions that they could answer by doing specific tasks using the software. They were able to make angles of varying sizes and the like. This software was intended to add a visual effect to the learning, helping students to learn by doing. The students worked in pairs and negotiated solutions. In one study, "Dynamic geometry programs ... like word processors and spreadsheets, … are tools that can be used to create and support student centered learning environments." (Hannafin, 2004). "Low-ability students scored higher in the less structured program, whereas high- and medium-ability learners performed better in the structured program." (Hannafin, 2004).

One of the failures regarding the use of the software fell with teachers' influence. "… The teacher creates his own rules for using the computer, which provide affordances and constraints to students' computer engagement. These rules generally discourage children from exploring the software or acting creatively on the computers, as in this case as least, the teacher feels threatened by his own relative lack of knowledge when using the computer." (Hardman, 2005). So, although the tool used properly could have created a situation whereby the student discovered something valuable, the teacher sabotaged the experience by greatly constricting the software's use in the study.

Math Insight Software
Math Insight Software uses software and is problem based; "in our field tests, the use of fictional characters engaged in "real-life" problem situations proved highly engaging to students…" (Zucker, 2006). These videos were used to enhance standard mathematics courses, and while they had moderate success with students, school districts were running into financial issues which made acquisition of the software ultimately undesirable. In fact, "…the passage of the No Child Left Behind Act of 2001 … suddenly increased the pressure on schools to produce rising test scores in mathematics … Software aiming at problem solving more generally was of less interest to schools." (Zucker, 2006).

Student-Centered Instructional Design
The key to effective teaching is the adoption of a student-centered Socratic method of teaching. As such, tools that the instructor uses can be non-technology based, or technology based. Textbooks that encourage the student to do investigative learning show promise as tools for student-centered learning as they promote discovery and inquiry. Evidence shows that "…as students are solving a problem, they need to implement strategies, use resources, and evaluate their progress so that they are aware of and critically examining their own decision making." (Underwood, 2005). "Inquiry, or investigative methods in mathematics teaching are seen to fit with a constructivist view of knowledge and learning: they demand activity, offer challenges to stimulate mathematical thinking and create opportunities for critical reflection on mathematical understanding." (Jaworski, 2006). Therefore, this type of inquiry-based methodology is highly recommended and does not necessitate the use of technology, although technology has proven to be helpful. (National Council of Teachers of Mathematics [NCTM], 2006).

Collaborative textbooks with teacher guides encourage students to work out solutions in a group environment. In particular this can benefit lower-ability students because they can see how higher-ability students go about solving a problem. As Jaworski (2006) attests, "A social-constructivist perspective sees discussion, negotiation and argumentation in inquiry and investigation practices to underpin knowledge growth in mathematics, in teaching mathematics and in mathematics teacher education."

Conclusions
The real key is educating instructors to use an Inquiry model to teach mathematics. If the students know they are expected to participate, they do. Their minds are better focused, and more of the material is learned. Technology, while not strictly necessary, can soften the intensity of this Socratic method, and

take a bit of the burden off of the teacher. The student can interact with games to learn more complex mathematical ideas, and a major benefit of games at this level is the improved motivation factor. Students can also work with other students to gain insight into successful problem solving strategies. As Hannafin (2004) stated, "… activities must be structured and orchestrated to guide students to the point where conjecture is possible."

Teacher belief systems are at the root of resistance to any new advances in technology integration. Even when technology is introduced, generally they have been of little help. Indeed, "thousands of drill and practice and tutorial programs have been developed and used in schools with very little impact." (Kearsley, 1994). And according to Beswick (2007), "Among factors that militate against achieving such a classroom climate, he included the decreased likelihood of teachers, as a result of escalating demands on their time, continuing their own learning of and about mathematics and its teaching.". A key may be computer games, which are "fun and challenging; they exercise a student's problem-solving and decision-making skills, and they can be used in any subject domain." (Kearsley, 1994). These types of approaches are important; "many have suggested that multiple representations may enable students to focus on different aspects of a mathematical idea." (Hardman, 2005). Of course, central to implementation is teacher training, as "… improvement of mathematics learning in classrooms is fundamentally related to development in teaching…" (Jaworski, 2006).

Technology just for the sake of technology is ill advised. First and foremost, a well-planned inquiry design is needed to encourage and ensure successful student participation. Student-centered learning is critical. The student must take ownership of his or her own education. Once this is in place, one can thoughtfully introduce technology as an aid to help engage students. Project-based activities also bring a sense of realism to the student, a concrete example of how math can be used. Beswick (2007) states that it's important to "focus on the students-their needs, backgrounds, interests and particularly their existing mathematical understandings."

True change will happen when teachers are closely assisted through a new technological environment. Teacher training and mentoring are necessary to make significant advancements in the acceptance of technology in mathematics classrooms. Indeed, "… introduction of a new tool - the computer - into the classroom shifts a teacher's pedagogical practice." (Hardman, 2005).

A good instructional design model is of primary importance, one that incorporates an inquiry or Socratic methodology. Technology will help. Indeed, "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning… Technology should be used widely and responsibly, with the goal of enriching student's learning of mathematics…. [They] furnish visual images of mathematical ideas, they facilitate organizing and analyzing data, and they compute efficiently and accurately… When technological tools are available, students can focus on decision making, reflection, reasoning, and problem solving." (NCTM, 2006). Success will come with proper support for teachers from the administration primarily in the form of training and ongoing support to ensure implementation of the technology and the design.

References

Beswick, K. (2007). Teacher's beliefs that matter in secondary mathematics classrooms. *Educational Studies in Mathematics, 65,* 95-120.

Bjorklund, D. F., & Bering, J. M. (2002). The evolved child: Applying evolutionary developmental psychology to modern schooling. *Learning and Individual Differences, 12,* 347-373.

Clarke, T., Ayres, P., & Sweller, J. (2005). The impact of sequencing and prior knowledge on learning mathematics through spreadsheet applications. *Educational Technology Research and Development, 53(3),* 15-24.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development, 53(4),* 25-39.

Hannafin, R. D. (2004). Achievement differences in structured versus unstructured instructional geometry programs. *Educational Technology Research and Development, 52(1),* 19-32.

Hardman, J. (2005). An exploratory case study of computer use in a primary school mathematics classroom: New technology, new pedagogy? Research: Information and communication technologies. *Perspectives in Education, 23,* 99-111.

Jaworski, B. (2006). Theory and practice in mathematics teaching development: Critical inquiry as a mode of learning teaching. *Journal of Mathematics Teacher Education, 9,* 187-211.

Kearsley, G., Lynch, W. (1994). *Educational Technology: Leadership Perspectives*. Englewood Cliffs, NJ: Educational Technology Publications.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Renninger, K. A., Sinclair, N., Hand, V. M., Alejandre, S., Stohl, H., & Underwood, J. S. (2003). *Interest and motivation for learning mathematics with online interactive challenge problems*. Paper presented as part of the symposium, Interest and Motivation for Computer-Based Learning, European Association for Research on Learning and Instruction. Padova, Italy.

Underwood, J.S., Hoadley, C., Lee, H. S., Hollebrands, K., DiGiano, C., & Renninger, K.A. (2005). IDEA: Identifying design principles in educational applets. *Educational Technology Research and Development, 53(2),* 99-112.

Zucker, Andrew A. (2006). Development and testing of math insight software. *Journal of Educational Technology Systems, 34(4),* 371-386.