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Middle School Science and Mathematics Teachers and Their Students: Adapting to Technologies that Work

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"The focus of this article is to review the literature primarily from the 1990s- on the use of computer-related technologies for middle school mathematics and science."

Abstract

The purpose of this paper is to review the literature on the use of computer-related technologies in middle school mathematics and science settings. These technologies include CD-ROMs, hypermedia and websites, calculator-based laboratories (CBLs), and microcomputer-based laboratories (MBLs). Overall, the use of these technologies has led to positive results in the classroom. The technologies used for data collection can serve as a vehicle for integration of math and science topics. Previous studies indicate that technology can meet the differing needs of varied learning types and can lead to increased knowledge retention. Professional development for teachers can lead to successful technology integration in the classroom if issues of administrative support, classroom management, and access to computers are addressed. There are a few keywords utilized in this literature review:

- ***middle school science and mathematics teachers***
- ***middle school students,***
- ***inquiry-based activities,***
- ***teacher licensure,***
- ***inservice teachers,***
- ***rural middle school teachers,***
- ***hypermedia assisted instruction,***
- ***animated graphics,***
- ***CD-ROM,***
- ***calculator-based laboratory,***
- ***and microcomputer-based laboratory.***

The middle school provides an environment where true interdisciplinary inquiry activities can be cultivated. Mathematics and science are a natural pairing for interdisciplinary collaboration: students can use data collected in experimental situations to learn analysis, model building and equation fitting, making predictions, and communicating findings. The pairing of math and science can be achieved by teaming teachers - an important factor in forming interdisciplinary cooperation, the social environment necessary for diffusion of innovation, and a support structure for adopting math and science reforms (George, Stevenson, Thomason, & Beane, 1992; Rogers, 1995; Sparks, 1997).

The focus of this article is to review the literature -primarily from the 1990s- on the use of computer-related technologies for middle school mathematics and science. We investigated the structure of the middle school as the environment for these technologies, the benefits of varying technologies, student issues surrounding the technologies, and the professional development issues surrounding teachers' implementation of technology in the classroom.

Several types of technology have recently become available for science and mathematics classrooms: CD-ROMs for computer-aided instruction (CAI) and hypermedia-assisted instruction (HAI) as exemplified by the Web; microcomputer-based laboratories (MBL); and calculator-based laboratories (CBL). These technologies can be combined with principles of best practice to support a learning environment that integrates active learner involvement, critical thinking, and inquiry. This technological environment in mathematics and science classrooms can serve the needs of many types of learners and can be an asset for the teacher willing to approach students as a facilitator (Brasell, 1987; Cassity, 1997; Heller, 1990). The use of technology tools can promote inquiry-based activities by allowing collection of large numbers of data points, short time intervals, and quick graphing. However, few teachers are fully aware of the impact of the tools on data gathering which may foster further exploration.

Professional development for inservice teachers may fill this gap in awareness and technical skills, but teachers need to participate in the professional development and achieve meaningful learning. Teachers' adoption of the technology tools may depend on accompanying issues with technical support, administrative support, subject matter preparation, student behavior, and management. For middle school students, technology tools may introduce distractions from the science and math content as well as misconceptions. Literature on each of these themes was reviewed to help discern emerging patterns in the findings and to form a basis for further research.

Middle School

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Middle schools emerged in 1960s school district reorganizations as a bridge between elementary and high schools. The organization of middle school is based on the special characteristics of early adolescents and most are comprised of grades 6 through 8 (Alexander & George, 1981). The middle school movement has grown in the United States over the years: from 1101 middle schools in 1968 to 4329 in 1986 (Alexander & McEwin, 1989).

Many middle schools are organized around interdisciplinary teams of teachers with a group of students rotating among the team's teachers during the day. Each team can use cooperative planning and their joint comprehensive knowledge of the students to plan for the varied instruction needed by the students. Teaming can help encourage student exploration of skills and allow them to experience integrated themes from different academic perspectives (Capelutti, Stokes, Bergmann, & Eichhorn, 1991).

Another goal of many middle schools is participation by all in a full-scale exploratory program. Mathematics and science teachers can make a natural pairing in this atmosphere. A 1988 national survey showed that all middle school students take mathematics courses and 95% take science courses (Alexander & McEwin, 1989). Problem solving and critical thinking skills are important objectives for both mathematics and science teachers. These teachers bring different perspectives and methodologies to the planning process. With the availability of technologies such as CD-ROMs, hypermedia, CBL, and MBL, teachers have new powerful tools for merging mathematics and science problem-solving in the classroom.

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CD-ROMs and Hypermedia

"Science and mathematics are some of the content areas best suited to discovery learning, and thus excellent test beds for the use of computers and technology."

CD-ROMs (Compact Disc Read Only Memory) were introduced as a new form of data storage for microcomputers. In the mid-1990s, CD-ROM drives became standard equipment on most new computers. Between 1988 and 1995 the number of public schools using CD-ROMs had increased 250% (Plotnick, 1996). During the 1997-98 school year, 97% of U.S. public schools reported using CD-ROMs (Market Data Research (MDR), 1999.) With a data capacity of 650 megabytes (MB) (the equivalent of approximately 450 diskettes), the popularity of CD-ROMs rose along with the increased use of multimedia and hypermedia. Software with elements of text, hyperlinks, graphics, photographs, sound, animation, and video can be packaged together on a single CD-ROM. The software generally allows nonsequential or nonlinear access to the elements providing for flexibility and interactivity (Levin & Matthews, 1997.)


Image obtained from Key Photos For Windows.

CD-ROM software packages with multimedia elements inspired educators to study their teaching and learning potential. These elements are also present in many Web pages for education. Multimedia and hypermedia software share characteristics with incidental learning and discovery learning. There is unplanned learning that can take place and opportunities can be provided for learners to explore alternatives and study relationships (Heller, 1990). With its multimodal presentation, this type of software has been found effective for accommodating the needs of different learners in learning cognitive and procedural information (Ayersman, 1996). Science and mathematics are some of the content areas best suited to discovery learning and thus excellent test beds for the use of computers and technology. Rieber has worked extensively on the effects of animated representations on incidental learning [Rieber, 1991). He concludes that even though students extract incidental information from animated graphics without risk to intentional learning, they are dangerously prone to developing a scientific misconception.

Middle school students need to know at least the technology's representational aspect. The ability to manipulate and control different representational parameters allows students to explore new possibilities and inquire within the science itself. With the help of computers, a constructivist-oriented learning environment can be created in the classroom.The computers give students plenty of opportunities to test their ideas [Goldberg, 1995]. Computers are not just part of the curriculum, but the whole curriculum is based on the use of computers. All classroom activities are not done on the computers, the computers are used when necessary. In Goldberg's project the students become more aware of their own learning by writing journal reflections and extensive learning commentaries. The computer also acts as a source of ideas that can challenge the students without the image of authority that teachers used to have in science classrooms. Now the students have the responsibility to use the technology tools for their own benefit, not as distracting elements.

Linear and nonlinear presentation techniques can both be utilized within multimedia software. Each of these techniques has advantages and disadvantages for middle school students. For instance, a primary choice of entertainment for children is cartoon animation. This could suggest that linear animation software or video will maintain the attention of the children and therefore be able to stimulate their interest in the sciences. Handal and his group found that there were significant differences between the students' ability to recall and comprehend complex subjects as presented by linear multimedia as opposed to those presented through printed text. Furthermore, linear animated material used as a didactic tool was easier for students to follow and manipulate in comparison to nonlinear software materials (Handal, 1999).

Hypermedia-assisted instruction has been found to include numerous advantages: easy tracking and searching of references, individual exploring of both academic and nonacademic material, and keeping many threads of inquiry alive at once, allowing discussion about findings. Less obvious are the disadvantages which also exist: disorientation, cognitive overload, flagging commitment, and unmotivated rambling (Heller, 1990).

Calculator-based Laboratory

Calculator-based laboratory (CBL) is a system which includes a graphing calculator, an interface box, and probes. This system is used to measure and store data of many kinds and display the data as a time graph soon after the measurements are made. Graphing calculators have become more common in mathematics classrooms during the past decade while the CBL system is becoming more common in science classrooms (Cassity, 1997; Clayton, 1990). CBLs are low in cost compared to other electronic data collection systems and are portable. The main producers of CBL equipment in recent years are Texas Instruments, Casio, and Vernier Software. The literature on the use of CBL consists mainly of practitioner articles, explaining ideas for use of the system in the science classroom (Brueningsen & Bower, 1995; Reno & Speers, 1995). There is apparently a need for more research studies on the educating of middle school mathematics and science teachers in the use of CBLs.


TI-83 calculator with CBL unit and pH probe. Image provided by author Lisa L. Grable.

Microcomputer-based Laboratory

Microcomputer-based laboratory (MBL) include the use of a microcomputer with an interface box and probes to collect data. Probes are designed to collect all sorts of experimental variables including temperature, pH, distance, force, light intensity, and dissolved oxygen, to name a few. This technology is available to classroom teachers since the mid-1980s when Robert Tinker, Ron Thornton and associates at TERC produced the "red box" interface for the Apple IIe (Thornton, 1985; Tinker, 1985). The MBL system can be used to collect a large number of data points over a period of time, store it, and see the results graphically in real time. MBL interface boxes, software and probes have been available from Vernier Software and Pasco Scientific in recent years.

MBLs gained wide acceptance in college and high school science classrooms after Heather Brasell's seminal study comparing traditional paper-and-pencil graphing methods with the instantaneous displays of the MBL. Students have a significant increase in retention of graph understanding when they see the graph instantaneously while the data is being collected (Brasell, 1987). MBLs have not been widely-used in middle school classrooms in North Carolina for science or mathematics. More research on the educating of middle school mathematics and science teachers to use MBL in the classroom and the learning of middle school students while using MBL would be helpful.

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Inservice Programs


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Technology has become an integral part of society today. As pressure is exerted upon educational systems to implement instructional technologies, teachers' abilities to accept change and adopt innovations become key factors for success. The concept of literacy in science and mathematics has expanded in recent years to include the use of computers and other interactive technologies as necessary components (American Association for the Advancement of Science (AAAS), 1989; National Council of Teachers of Mathematics (NCTM), 1998). Computers are used in numerous job situations such as office work, newspaper layout, and research. Business and industry leaders would like students to receive some technology training while they are in school, before entering the workplace. This is a source of pressure on teachers (Ingram, 1994). Finding successful methods for educating teachers to use new technologies and working with them to adopt new pedagogical approaches is a widespread concern, judging from the number of articles in the literature. Inservice education is seen to be one possible method for teaching teachers to use technology themselves and introduce it into classroom teaching.

"Computer technology has not had the impact expected in the schools because of inadequate preparation of teachers (Dupagne & Krendl, 1992; Ingram, 1994). "

There are three approaches to integrating new technology into the classroom. Teachers can work as individuals, teaching themselves to use the new technology or getting help on their own. The decision to use a technology can come from above, with a school district providing equipment and some type of staff development education. Staff development on the new technology can be offered by an outside agency and teachers can volunteer to participate. Staff development for inservice teachers has been available for many years and has been studied since the 1960s. Many of these studies target teachers' gain in content knowledge or measure affective impact during the course of the professional development by collecting data at the beginning of the institute, in the form of tests or surveys, and collecting data again at the end of the institute (Dupagne & Krendl, 1992; Fenstermacher & Berliner, 1985; Lock & Dunkerton, 1989). The findings from these studies have not revealed much about teachers' adaptation and integration of workshop instruction into their own classrooms after the workshop experience.

Recently, more studies have been designed to follow the teachers during the school year after the institute (Barrow & Sawanakunanont, 1994; MacArthur et al., 1995; Shroyer & Borchers , 1996). The impact on the teachers have been reported without definitive knowledge of the teachers' performance prior to the institute. Using a constructivist framework, evaluators would recognize that teachers do not begin the institutes as "blank slates," rather they begin with a history of classroom practice and beliefs that become part of the institute (Arßmbula-Greenfield & Feldman, 1997; Brooks & Brooks, 1999).

Recent research studies indicate a set of factors that have an effect on the success of introducing change into the schools. Using technology as an integral part of teaching science and mathematics is such a change. Computer technology has not had the impact expected in the schools because of inadequate preparation of teachers (Dupagne & Krendl, 1992; Ingram, 1994). More technology inservice education can help meet this need. Teachers lack of technology preparation is highlighted in the research literature. Ingram found 92% of recent education graduates would most have liked training in the use of computer technology to be added to their teacher preparation program. Half the teachers surveyed by Buchsbaum (1992) had not been through a technology training course. These teachers wanted training in how to use hardware, classroom management, and distance learning. In addition, teachers are isolated, making it difficult to share changes with other teachers. A U.S. Department of Education report (1986) found that up to 45% of teachers have no contact with each other during the school day.

Bosch (1988) states that the interaction of innovation, institution, and individuals are the mix that set the stage for technological change in the schools. Inservice education presents the innovation, in this case technology, to the individuals, in this case the participating teachers. The institution in which the teacher works, the school and the school district, must somehow be brought into the inservice picture. Ingram (1994) reports that teachers change their behavior in the classroom when staff development programs convince them that the changes they make will be rewarded by their institution and that the changes will make their jobs easier and more satisfying.

The effect of computers in schools depends on the success teachers have with integrating educational goals and the curriculum (MacArthur & Malouf, 1991; Winkler, Shavelson, Stasz, & Robyn, 1985). As Bosch (1988) states, "Too often, training is seen as a change agent merely by providing needed knowledge and skills. For innovation to succeed and change to occur, training efforts must become more comprehensive in scope and content" (p. 331). For example, teachers need both inservice education and continuing support for mastery of computers. It's a gradual process that usually takes several years (Bosch, 1988; Sheingold & Hadley, 1990).

Some unexpected results came out of recent inservice programs studied. Ten out of 24 teachers in Lock and Dunkerton's study (1989) who did not use biotechnology-related theory before the treatment made use of it in their classes after the workshop. However, eight of the teachers who attended still did not use biotechnology in their teaching after the staff development.

This may be explained by MacArthur et al.'s (1995) findings that an unexpected obstacle to success in implementing technology was that the teachers became competent with computers but were overwhelmed by a fear of their students' misbehavior. The teachers trying to introduce technology in their classrooms expressed "doubts about handling the potent mix of novel atmosphere, student excitement, and their own relative inexperience with computers" (MacArthur et al., 1995, p. 55).

Every school in Buchsbaum's (1992) Washington, DC study had 30 - 40 computers, but because of school-day scheduling only 1/3 of the teachers in any school were able to use these computers. The training center estimated that 1/4 of teachers in the school district used computers regularly. Apparently training is not enough: access to computers and actual practice with students in a technology environment are very important.

Conclusion

It is historically a difficult task to integrate new technology into instruction in the classroom. A variety of reasons for teachers resistance to implementing new technologies have been explored. Most research has been done in the area of resistance to integrating computers into classrooms (Dupagne & Krendl, 1992.) The conditions for resisting change can be transferred to new technologies for learning, such as CD-ROM, hypermedia, CBL, and MBL. How teachers may eventually make use of the potential of the assets of the technology and how student learning is affected by the technology remain great concerns for schools and society.

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Research can help inform practice in the use of computer-related technologies for middle school mathematics and science. Middle schools structured around theories of early adolescent development provide a natural environment for the teaming of mathematics and science teaching with technology as a means of interdisciplinary collaboration. Research has shown that technology can meet the differing needs of varied learning types and can lead to increased knowledge retention. Further studies are needed to determine processes of learning while interacting with the Web and the effects for students of using CBLs for middle school math and science learning. The literature indicates that professional development for teachers can lead to successful technology integration in the classroom if issues of administrative support, classroom management, and access to computers are addressed. Further studies are needed that examine the process of technology adoption specifically by mathematics and science teachers in middle schools. In addition, studies are needed to investigate effective models for teacher workshops that incorporate math and science integration, inquiry learning, and technology for data collection and analysis.

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