Identifying Factors that Impact Science Teachers’ Sustained Integration of Instructional Technology

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Abstract

The call for integration of technology into science education classrooms to promote science inquiry and achievement continues to gain attention. This review of the literature identifies middle school science teachers’ perceptions of integration of technology into the curriculum and examines existing models of integration declared by research to be effective. Selected articles are synthesized into a summary table, which identifies and organizes information from each article in respect to technology modes, technology integration (and frequency of use), challenges facing teachers and recommendations for utilizing technology. Few studies have directly assessed teachers’ frequency of use and perceptions of technology integration within the middle school science curriculum, and a limited number of recommendations for effective integration of technology to promote science inquiry have been made.
Identifying Factors that Impact Teachers’ Sustained Integration of Instructional Technology

As researchers, teacher education programs and school systems address the call for science educators to integrate technology into their classes, it is wise to review the research regarding teachers’ perceptions of technology integration. This study reviews the literature in order to identify teachers’ perceptions of technology integration within the middle school science curriculum, and examines current models of technology integration suggested by research as being effective. Information obtained from the literature review is synthesized into a summary table. The table is constructed to identify and organize information from the literature regarding modes of technology and technology integration, teachers’ frequency of technology use, challenges teachers face regarding technology use, and possible recommendations for middle school science teachers’ use of technology as suggested by the literature.

Background

A project currently underway at the University of Kentucky (UK) seeks to assess *How Distance Learning for Teachers Can Enable Inquiry Science in Rural Classrooms*. The project, funded by NSF, supports the initiative to improve science education in rural Appalachian middle schools by promoting teachers’ use of inquiry and technology. If these efforts are to be successful, project members must have a sense of middle school science teachers’ needs and opinions regarding technology for inquiry learning. This study asks questions of the literature regarding middle school science teachers’ perceptions of instructional technology integration into their classroom.

The importance of technological literacy has become deeply embedded within the nation’s educational policies. The No Child Left Behind (NCLB) legislation enacted in 2002
addresses the inclusion of instructional technology with an emphasis on the importance of integrating technology into all areas of K-12 education (U.S. Department of Education, 2001). Mandated by NCLB, The National Education Technology Plan (U.S. Department of Education) was officially released in January 2005. Driven by the goals of NCLB, The National Education Technology Plan (2005) presents major action steps and recommendations for improving the integration of educational technology within the nations’ schools.

This emphasis on technology integration by the country’s educational policies has been driven in part, by the need for improved performance in mathematics and science among the country’s student population (National Center for Educational Statistics, 1999). Over 20 years ago, A Nation at Risk (National Commission on Excellence in Education, 1983) warned policymakers and the public alike of the declining level of student achievement. Specifically, the report highlighted the decline in science achievement scores amongst 17-year-old students as measured by national assessments of science. Recent studies published by the Third International Mathematics and Science Study (TIMMS) support this reported decline in science achievement (NCES, 2001). Now, current educational legislation seeks to combat the decline in student science achievement through the integration of educational technology (NCLB, 2001).

Legislation calling for the integration of educational technology is supported within science education by the National Science Education Standards (NSES). Proposed in 1995 by the National Research Council (NRC) and adopted by organizations including the National Science Foundation (NSF) and the National Science Teachers Association, NSES dictate that students at all levels (K-12) should have an understanding of science and technology (NRC, 1996). The NSES also emphasize the role of technology-use in promoting the development of student’s skills in practicing and understanding science inquiry.
The process of inquiry, in combination with science content, is now a central tenet within the NSES and accepted by many within the field of science education as best practice for promoting the development of students’ science literacy (Gerber & Brovey, 2001). Based on constructivist reform, learning by inquiry specifies that knowledge and understanding must be actively acquired, socially constructed, and created for individualized meaning (Perkins, 1999). The process of inquiry requires the learner to create, test, and evaluate hypotheses, while utilizing skills in deduction, problem-solving, and critical and creative thinking (Windschitl, 2000). The notion of teaching science through inquiry dates back to the early 1900’s and has been found effective in promoting science achievement (Ediger, 2001). Yet, many teachers find the task of maintaining science content while also incorporating inquiry, as dictated by the NSES, daunting (Barab & Luehman, 2003). Thus, more educators and researchers have turned to technology-driven learning activities as a means of providing opportunities for integrating both content and inquiry into the science classroom. (Edelson, 2001).

Research in support of the acceptance of instructional technology as a means of improving science education and inquiry has been mixed. General evidence supports a positive relationship between technology use and student achievement (Papanastasiou, Zembylas, & Vrasidas, 2003). Most of this research focuses on computers as the primary form of instructional technology used within the classroom. According to the National Assessment of Educational Progress (NAEP), 4th and 8th grade students taught by teachers who regularly utilized computer-based instructional technology outperformed and showed greater achievement than 4th and 8th grade students whose teachers did not incorporate the same technology (NCES, 2000). Although less research has specifically examined technology integration and student achievement within the science curriculum, some of these general trends are also supported (Windschitl, 2000). In
some studies, computers have been utilized as a tool to improve science achievement of students (Hurwitz & Abegg, 1999; Dutt-Doner, Wilmer, Stevens, Hartmann, 2000).

Not all research has supported a positive relationship between technology use and increased science achievement (Wenglinsky, 1998). The use of some computer-based technologies has not proven more effective in increasing science achievement than the traditional, or paper-based, approach to learning (Williams, Hemstreet, Liu, Smith, 1998). These conflicting results bring to light factors contributing to the successful integration of educational technology. Access to or use of technology alone may not prove beneficial in improving student outcomes. The success of improving students’ inquiry skills and science achievement with the aid of educational technology appears to lie within the mode of technology selected and its application in the classroom (Papanastasiou, et al., 2003).

This perception of technology integration places a great deal of responsibility on the classroom teacher. Data provided by Teachers’ Tools For the 21st Century: A Report on Teachers’ Use of Technology (NCES, 1999), suggests that, despite the attention paid to increasing the availability and access to technology within the nation’s schools, considerably less emphasis has been placed on preparing and supporting teachers effective integration of technology in the classroom. This is evident as the NSES places importance on the role of technology within science instruction and inquiry, yet does not provide teachers with a clear outline of the role of technology and how it may best be used to promote the development of scientific inquiry skills (Windschitl, 2000).

There is little indication that science teachers are systematically integrating and using technology long-term (Milkin Exchange, 1998). Many teachers report a lack of success in their attempts to find effective methods and techniques for integrating technology into their classroom
(Rakes & Casey, 2002). One possible means to facilitate effective technology integration is by implementing learning-centered, or inquiry curricula that integrate technology. Unfortunately, the use of science curricula materials that incorporate instructional technology is not currently widespread (Price, Cates, Bodzin, 2002). With this lack of established science curriculum, trainers and administrators must provide teachers with the on-going training and support needed to assist them in integrating technology into their science curriculum.

Teacher training regarding the correct and appropriate use of technology within the science curriculum is not the only key factor in supporting technology integration. A vital determinant in the effectiveness of technology integration is the skill and attitude of the teacher (Bitner & Bitner, 2002). To be effective in teaching, shaping, and supporting teachers’ sustained integration of technology in their everyday science curriculum, models for technology integration in curriculum and instruction must identify and address factors that influence teachers’ use of instructional technology (Dexter, Anderson, & Becker, 1999; Wetzel, 2001).

Techniques

This study reviews the literature in order to identify teachers’ perceptions of technology integration within their curriculum, and to examine current models of technology integration suggested by research as effective. Questions regarding teachers’ perceptions of technology integration in their science class are answered through a review of the literature as found through the ERIC and Professional Development collections hosted by EBSCOhost. The computer-based literature searches were conducted using Keywords such as Teacher Attitudes, Science Instruction, Educational Technology, Technology Integration, and Inquiry. Relevant research was also identified using the reference sections of articles found through the computer-based literature review. To provide a relevant and recent account of the literature for the purposes of
this investigation, selection criteria included works published after 1998 in a peer-reviewed journal, national conference proceedings or dissertation.

In order to serve the direct needs of the funded project, the literature produced from this initial search was limited further to include only studies conducted in middle school science classes that emphasized inquiry-based technology integration. Once these middle school studies had been identified, the literature was restricted further to include only those studies that included the perceptions of the teachers while integrating inquiry-based technology in their middle school science class. Based on this stated criteria, eight studies were selected for inclusion in this literature review. The content retrieved from the literature was synthesized according to factors including type of instructional technology identified, teachers’ frequency of use, teachers’ concerns/challenges regarding use, and recommendations for teachers’ use in classroom.

Results

The summary table was constructed to identify and organize information from the selected literature regarding modes of technology for integration, teachers’ frequency of technology use, issues/challenges teachers face regarding technology use, and possible recommendations for teachers’ integration of technology as suggested by the literature. Author and date of study identify the selected studies retrieved from the specified literature search.
<table>
<thead>
<tr>
<th>Author(s) &amp; Year</th>
<th>Grade(s)</th>
<th>Length of Study</th>
<th>Mode of Technology</th>
<th>Teacher Concerns with Technology</th>
<th>Recommendations for Technology Integration</th>
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<tr>
<td>Bowman, Koirala, Edmonds, &amp; Davis (2000)</td>
<td>7</td>
<td>1 year</td>
<td>Graphing Calculators</td>
<td>*Teachers’ unfamiliarity with technology</td>
<td>*Teachers need classroom support and modeling</td>
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<td>Dutt-Doner, Wilmer, Stevens &amp; Hartmann (2000)</td>
<td>6 – 8</td>
<td>6 weeks</td>
<td>Internet: WebQuest</td>
<td>*Students’ ability to find credible information *Computer access</td>
<td>*Teachers’ need adequate planning before implementation *Prepare students to use technology *Evaluate student performance throughout process *Tailor activity to meet level/experience of students</td>
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<tr>
<td>Mistler-Jackson, Songer, 2000</td>
<td>6</td>
<td>8 weeks</td>
<td>Internet Software -Kids as Global Scientists (KGS)</td>
<td>*Classroom management issues involved with technology *Unreliability of technology</td>
<td>*Scaffolding Internet curriculum *Use technology to ask authentic questions *Provide adequate time for in-depth investigation of topic</td>
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<tr>
<td>Roth, 2001</td>
<td>6 &amp; 7</td>
<td>4 months</td>
<td>Simple Machines</td>
<td></td>
<td>*Activities should focus on designing and testing artifacts *Activities should allow students to analyze and explain performance of artifacts</td>
</tr>
<tr>
<td>Yang, 2002</td>
<td>8</td>
<td>1 semester</td>
<td>Laptops</td>
<td></td>
<td>*Make use of laptops as cognitive tool *Employ a constructivist approach to technology integration *Provide curriculum support *Logistics of Classroom *Reduce Distractions</td>
</tr>
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<td>Baggott la Velle, McFarlane, Brawn, 2003</td>
<td>7</td>
<td>2 sessions</td>
<td>Simulation Software</td>
<td>*Preparation</td>
<td>*Preparation</td>
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<td></td>
<td>- Crocodile Clips</td>
<td>*Representation</td>
<td>*Representation</td>
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<td></td>
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<td></td>
<td>- Circuit Boards</td>
<td>*Instructional Selection</td>
<td>*Instructional Selection</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>*Adaptation</td>
<td>*Adaptation</td>
</tr>
<tr>
<td>Kim &amp; Grabowski, Song, 2003</td>
<td>6 – 8</td>
<td>4 months</td>
<td>Web-based program</td>
<td>*Discrepancy between established teaching methods and new teaching methods</td>
<td>*Connection and balance of established teaching practices with new teaching approaches</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- Kids as Airborne Mission Scientists (KaAMS)</td>
<td></td>
<td>*Provide teachers with specific information or guidance about how to incorporate a variety of instructional approaches suggested in a new innovated learning program</td>
</tr>
<tr>
<td>Pedersen &amp; Liu, 2003</td>
<td>6 – 8</td>
<td>1 year</td>
<td>Educational Software</td>
<td>*Grading students during performance</td>
<td>*Provide scaffolds for students with special needs</td>
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<td></td>
<td></td>
<td></td>
<td>- Alien Rescue</td>
<td>*Time and information needed to prepare students for standardized tests</td>
<td>*Support factual knowledge acquisition</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>*Appropriateness for students with special needs</td>
<td>*Capitalize on the multimedia affordances of computer technology to create new learning experiences for students</td>
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</table>

Table 1. Summary of Research Studies
Summary

This table serves as a resource for educators, administrators, researchers, and trainers to quickly identify literature relevant to the successful inquiry-based integration of technology within the middle school science class. The results below provide a general summary of the literature identified as relevant for each research topic.

Modes of Technology for Integration

The term “technology,” as it relates to instructional tools within science education, is difficult to define. Teachers, administrators, and researchers alike view technology as encompassing a wide range of equipment. This review of the literature reveals the term “technology” most often implies computer-based instructional tools. The computer technology discussed within the literature is often broken down farther into the categories of Computer Software and Information Communication Technology (ICT).

Computer software, as a category of instructional technology, is a large umbrella that appears to include specific computer programs and applications, as well as the structural computer/laptop hardware itself. Computer software frequently referenced within the literature includes word processing, spreadsheets, graphic and design programs (Linn, 2003). The educational software most often referenced in the science education literature includes data analysis tools, simulations, and modeling software (Linn, 2003). Specific examples of these applications have been listed within the Table. A general reference to computer hardware is also found within this category of technology and has been cited as including the structural computer itself, laptops, and handheld devices such as palm pilots (Aleahmad & Slotta, 2002).

ICT is the other broad category of instructional technology most often cited within the literature. Similarly, ICT is a wide-ranging category that is most often described as including
communication via the World Wide Web. These Internet applications of instructional technology encompass such applications as information searches, email, online chats/discussion groups, and online classes or distance learning (NCES, 2003).

Not all references to technology within the science education literature are in regards to computer-based tools. Other forms of technology identified as applicable to the science classroom include simple machines and graphing calculators (Roth, 2001; Bowman, et al., 2000).

Frequency of Technology Integration

Although large-scale surveys have been implemented to assess the frequency of teachers’ technology integration within the classroom, less emphasis has been placed on assessing the integration of instructional technology within the middle school science classroom specifically. Data retrieved during this review of literature also revealed substantially less information regarding the frequency in which science teachers are implementing innovative technology within the curriculum. An investigation of teachers’ reported technology use reveals that much teacher use is simply to assist students in completing assignments through word processing (Meyer, Steuck, Miller, Pesthy, Redmon, 1999). One study that sought to address more innovative methods of direct technology integration found only 20% of teachers surveyed were integrating technology at lease once per week (Wiesenmayer & Koul, 1998). Similarly, research on post-treatment frequency data is also limited. Researchers often report an increase in teacher technology integration following treatment (Berber & Brovey, 2001); however, very few studies publish significant data in support of this claim.

Factors underlying this lack of data can be attributed, in part, to the difficulty many teachers have defining instructional technology. Yet, information regarding the pre and post-treatment frequency of technology integration is vital to evaluating the successful and sustained
integration of technology among science teachers. As researchers continue to design programs and train teachers to implement technology within the science classroom, data demonstrating pre- and post-treatment frequency of technology should be reported.

_Teachers’ Concerns/Issues Regarding Technology Integration_

Identifying the factors that impact science teachers’ use of instructional technology is essential to addressing and supporting their sustained integration of technology in the classroom (Dexter, et al., 1999; Wetzel, 2001). Many of the concerns identified through the literature as impacting teachers’ integration of technology can be observed according to the four main areas of accessibility to technology, classroom management issues, teacher familiarity with technology, and technology’s impact on the student.

One of the most cited concerns throughout the literature regarding the integration of technology within the science classroom is simply a lack of access to reliable technology (Dutt-Doner et al., 2000). From web-based innovations to data analysis software, this concern appears consistent regardless of the mode of technology being addressed. Even when technology is available, particularly with the increasing prevalence of computers (Bayraktar, 2001), science teachers report concerns regarding the unreliability of the technology (Mistler-Jackson & Songer, 2000) or the credibility of the information provided by technology such as the Internet (Wiesenmayer & Koul, 1998).

Another concern of science teachers frequently referenced within the literature involves management issues. Teachers report logistical concerns ranging from the extended time needed to evaluate computer software and plan technology integration within the curriculum, to the increased management required with the noise and activity level of the students when technology is integrated (Mistler-Jackson & Songer, 2000; Price et al., 2002). Teachers appear to have
concerns pertaining to their ability to manage the added distraction to students by having innovative technology within the class (Cifuentes & Hsieh, 2001).

Science teachers’ ability to manage technology within the classroom is not their only concern regarding their individual ability to integrate technology. Several studies have found that science teachers often feel unfamiliar with various forms of instructional technology (Bowman et al., 2000). They believe they lack the appropriate training to effectively integrate technology within the classroom (Matovinovic & Nocente, 2000), and do not think they will be adequately supported within their school (Price et al., 2002). With this perceived lack of training, many science teachers doubt their ability to adjust their current teaching methods to support the use of new and innovative technologies (Kim et al., 2003).

Additionally, science teachers appear to have several concerns in regards to the potentially negative impact of technology on the student. Teachers have raised concerns about integrating technology while still meeting science content requirements and preparing students for standardized tests (Matovinovic & Nocente, 2000). Teachers have questioned the methods for assessing student performance while using technology, and raise concerns about the appropriateness of various technologies for students with special needs (Pedersen & Liu, 2003). Although teachers, and students alike, have become more familiar and comfortable with the use of technology within their daily lives, several concerns still exist regarding the implementation of technology within the science classroom. These concerns must be addressed if teachers are to feel supported in their attempts to effectively integrate technology into the science curriculum (Lumpe & Chambers, 2001).
Recommendations for Technology Integration

Despite teacher concerns, some researchers and teacher trainers have conducted studies that demonstrate the successful integration of technology in the classroom to support science inquiry (Bowman, et al., 2000; Dutt-Doner, et al., 2000; Mistler-Jackson & Songer, 2000; Roth, 2001; Yang, 2002; Baggott la Velle, et al., 2003; Kim, et al., 2003; Pedersen & Liu, 2003). Reviewing the literature for such evidence can provide other teachers and trainers with recommendations for their improved technology integration into the science curriculum. Although many recommendations may be found, only those recommendations that directly address technology integration in support of science inquiry are included.

The most often cited recommendation for the successful implementation of technology within the science classroom is providing teachers with support and training (Price, et al., 2002). However, this support is often addressed in two forms. First, science teachers need technology support directly in the classroom. Teachers need training to specifically teach and model how to use the various forms of technology today (Bowman, et al., 2000). Even after such training, teachers need technology support within the school, which includes continued and frequent access to technology as well as support utilizing diverse computer configurations (Price, et al., 2002).

Training regarding the specific use of each form of technology is not enough. The most persistent recommendation throughout the literature for integrating technology within the science classroom is implementing technology in accordance with a constructivist, or learning-centered approach (Edelson, 2001, Yang, 2002). General recommendations for linking technology integration to constructivism or inquiry pedagogy have included teacher training on learner-centered approaches, implementing technology that provides scaffolds for students while also
creating new learning experiences, identifying a connection and balance of established teaching practices with new teaching approaches, and providing teachers with specific information about how to incorporate a variety of instructional approaches suggested within the technology program (Kim, et al., 2003; Pedersen & Liu, 2003). Several studies have provided examples with directions for implementing specific inquiry supported technology-centered activities within the grade-appropriate curriculum (Dutt-Doner, et al., 2000; Roth, 2001; Aleahmad & Slotta, 2002).

**Conclusion**

If instructional technology is to have the desired effects of promoting inquiry and improving science achievement as prescribed by the current educational legislation, teachers must implement technology appropriately within the classroom (Meyer, et al., 1999). However, administrators, researchers, and trainers share the burden of promoting sustained technology integration within the classroom. As investigators, teacher preparation programs and school systems continue to address the needs of educators to integrate technology into their science class, it is wise to review the research regarding teachers’ perceptions of technology integration. Identifying the factors that impact teachers’ ability to integrate technology into their science curriculum allows those connected with science education to be better equipped to design efficient models of technology integration. Science teachers will benefit from improved models of technology integration, which attend to teachers’ concerns and promote sustained technology integration.
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