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Integrating Technology and a Standards-Based Pedagogy in a Geometry Classroom: A Mature Teacher Deals with the Reality of Multiple Demands and Paradigm Shifts

ABSTRACT. A mature mathematics teacher (one in the latter stages of a successful career in teaching secondary mathematics) sought support in making a paradigm shift to a technology-integrated pedagogy in the context of a state's emerging standards-based curriculum. The teacher had concerns regarding his ability to make the paradigm shift, but he was willing to make the effort because he believed that integrating technology as an instruction/production tool would increase student achievement in mathematics. This article describes the teacher's experience. Students in two of his three high school geometry classes were introduced to altered teaching methods involving technology. The first class created instructional modules using presentation and Web page software, and a second

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class used student-created instructional modules. A third geometry class received traditional instruction based on text and lecture. Two topics, angles and circles, were taught using this format. Another topic, lines, was taught traditionally to all three classes. Interestingly, students across the three groups had numerically higher end-of-unit test scores for both lines and circles, much more acceptable to the teacher, than for angles. Recommendations are in order in regard to teacher support for technology integration. doi:10.1300/J025v24n01_06 *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com>*

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There is little debate in modern countries that technology is now an integral part of our everyday life experience. The call for schools to move to a more technologically integrated approach toward teaching and learning is resonating among government education agencies (Alberta's Commission on Learning, 2003); teacher groups (e.g., International Reading Association [Butler, 2002] and the National Council of Teachers of Mathematics [NCTM, 2000]); and university faculty (Mellinger & Powers, 2002). The overall implications of this approach, however, are yet to be clearly understood by the individual teacher. Nevertheless, the National Council of Teachers of Mathematics has categorically stated in *Principles and Standards for School Mathematics* (2000) that technology should be an integral part of the educational experience:

> The existence, versatility, and power of technology make it possible and necessary to reexamine what mathematics students should learn as well as how they can best learn it. In the mathematics classrooms envisioned in *Principles and Standards*, every student has access to technology to facilitate his or her mathematics learning under the guidance of a skillful teacher. (p. 25)

These NCTM *Standards* imply the need for a teacher in the classroom who is well prepared to decide if, when, and how technology can, will, or should be used. Such technology and curriculum-related decisions create for the teacher a unique set of challenges (Atkins & Vasu, 2000), especially when the teacher's knowledge of technology and its applications is limited to the more basic uses (e.g., word processing and an electronic grade book).

The classroom teacher requires a careful introduction to technology that allows for multifaceted issues to be considered before and during the change process (Bitner & Bitner, 2002; Brown, 1999; Huffman, Goldberg, & Michlin, 2003; Morrison, Lowther, & DeMeulle, 1999; Tomei, 2002). These issues can include motivation, support, changes in pedagogy, and selection of content and strategies. Other factors also play a key role in the process, such as the teacher's expectations for students, the teacher's initial familiarity with the technology, software choice, degree of integration required, quality of integration, instructional design of selected software, and scope and sequence of content to be covered. These and other factors affect the success of the teacher's negotiation of the technology integration learning curve (Monroe & Tolman, 2004).

The key to integrating technology into school classroom pedagogy is the teachers' ability to integrate simply and seamlessly their content teaching and technology within the course structure (Gooler, Kantzer, & Knuth, 2000). Typically, the innovative technology integration scenarios that have been reported (e.g., Boschmann, 1996; Dede, 1998; Dutt-Doner & Powers, 2000; Rice, Wilson, & Bagley, 2001) are the work of teachers who have a strong interest in technology. While there is a growing acceptance among teachers that the classroom learning environment can be enriched and learning tasks made more authentic with the integration of computer technology (Pisapia, Schlesinger, & Parks, 1993), widespread implementation is yet to be seen. Sandholtz (2001) concluded that increased access to technology in schools will mean little unless coupled with effective professional development and ongoing support for teachers. Johnson (1997) suggested that teachers who are pressed to develop a teaching paradigm that integrates technology may self-categorize as "pioneers" (they move on regardless of the problems), "waiters and watchers" (they sit and see how it develops), or "rebels" (they actively campaign against the change). Therefore, the success of technology integration in a course that is traditionally based on both text and lecture ultimately depends on the teacher's commitment to be a pioneer. Dwyer, Ringstaff, and Sandholtz (1990) reported that when teachers commit to integrate technology they develop through stages beginning at "entry," passing through "adoption," "adaptation," and “appropriation,” and ultimately reaching “invention.” According to Dwyer et al. (1990), the attainment of each stage requires a level of teacher support and professional development that is often scarce and left to the teachers themselves to find. This finding is supported by Haile (1998) who, in a study at the university level, found that where teacher support and professional development were provided in the implementation of computer technology, increased collaboration, enhanced student motivation and participation, and a higher level of student learning resulted.

Researchers have suggested that student motivation is one of the main benefits of technology integration (Crawford & Brown, 2003; Dede, 1998). Even so, the effect may have become less noteworthy in recent years because of the proliferation of video games, electronic home entertainment, and Internet connections in students’ lives outside of school. Although mature teachers who are moving into the latter years of their careers may have to cope with a steep learning curve in order to integrate technology (Monroe & Tolman, 2004), their students may see technology as merely an extension of their normal everyday world. Initial student excitement, if any, at an innovative technological approach may quickly fade when technology is the expected “normal use” from their perspective.

Teacher issues in integrating technology, particularly those of the maturing teacher, need to be researched in order to create an effective and supportive dynamic of change that will be sustained and productive over time. In a project involving a mature teacher integrating technology, not only do the developmental stages and the problems associated with each stage need to be considered and addressed, but also the nature of the support required.

THE PROJECT

A mature high school teacher, one in the latter stages of a successful career in teaching secondary mathematics from a traditional pedagogy based on text and lecture, sought help in integrating technology in his classes. Even though the teacher had concerns about his own ability to make the paradigm shift, his expectation was that integrating technology as an instruction/production tool had the potential for enhancing student achievement on content tests. This teacher was in the midst of an educational context in which teachers were being moved toward a standards-based curriculum. "Standards-based" in this article refers to the processes of teaching as well as the content learned as required by one state's curriculum standards (Hawai'i Department of Education, 2004). Hawai'i's curriculum standards in mathematics are closely aligned with the National Council of Teachers of Mathematics *Standards* (NCTM, 1991, 2000).

The project was sited in a large high school on the North Shore of O'ahu in the State of Hawai'i. The enrollment included approximately 2,000 ethnically diverse students spread among grades 7 to 12 taught by a faculty of 125 certified staff. In the high school, a full range of academic classes is offered, including the usual selection of mathematics classes from pre-algebra to calculus. The school has a partnership with a nearby, private, four-year university that offers baccalaureate degree programs including special, secondary, and elementary education. The project team involved in this project comprised the mathematics teacher and the technology director from the high school, along with two professors from the university education program. The mathematics teacher was a technology novice, using the computer personally for recording grades and word processing; he had not previously attempted to integrate the use of computers in his instruction. However he initiated the project described in this article and was willing to move up the technology learning curve required. Each of the university professors (the first two authors of this article) had previously taught at the high school level for many years in the areas of mathematics, science, and technology.

The teacher, with the help of the authors, developed a project to integrate technology into two of his three sections of geometry. These sections were intact groups, with students having been assigned their schedule based on availability of classes. Students in these sections were tenth through twelfth graders who had previously completed Algebra I. During the project, one class (Class A) would learn a set of geometry concepts and be assigned to create PowerPoint presentations, later to be transferred to a Web site using Claris Home Page. It was hoped that the benefits of the project could be made available to a wider audience by including them on the school's Web site. A second class (Class B) would then use these presentations as their medium of instruction. A third class (Class C) would continue to be taught in the teacher's traditional text and lecture method. Students would be assessed with end-of-unit tests constructed by the teacher to determine if they were making adequate progress.

The project was planned to begin during the first academic quarter of the school year with the preparation, planning, and ordering of equipment. The second quarter included training and upgrading skills of the teacher and students in Class A. During the third quarter, the actual instruction using technology integration was implemented, and teacher-constructed content tests were given to assess student achievement. The fourth quarter was a time for project evaluation and report writing.

In the initial stages of project planning, team members did not clearly understand the complexity of what was to be attempted and were not aware of all of the specific problems to be overcome. While the team had discussed the issues, they needed assistance in refining their ideas before beginning the implementation process with students. As a part of the preparation process, the team attended a conference for Boyer Foundation Grant recipients where additional information was gained. While there, project ideas were refined, visions shared, implementation issues discussed, and preliminary plans developed. At the end of the conference, all members of the team had worked together to develop a more cohesive understanding of the project's basic design and the problems that needed to be solved. This experience also served as an opportunity for the project classroom teacher to develop first hand an increased awareness of the possibilities of instruction aided by computer technology. His exposure to instructional possibilities was considered vital as he was to be voluntarily mentored through a large, partially unforeseen, paradigm shift. The conference also served to move him beyond the entry stage of development in computer knowledge as described by Dwyer et al. (1990).

Early in the first quarter in the academic year, four new computers, courtesy of a grant from the Boyer Foundation, were ordered along with memory upgrades and the supplies necessary to operate the complete hardware package for an entire school year. The intent was to ensure that movement toward the new teaching paradigm would not falter because of lack of necessary operating equipment in the classroom. The equipment purchase also served to alleviate teacher concerns related to lack of budgeted funding for the purchase of needed technology for classroom use.

During the second quarter, the focus of the project was on upgrading the mathematics teacher's technology skills, a step recommended by Snoeyink and Ertmer (2002). The teacher focused initially on increasing his comfort level with accessing resources on the Internet and producing presentations using PowerPoint and Web pages with Claris Home Page. He also generated for himself simple mathematics tasks such as formula use as well as small personal projects that would allow him to explore presentation and Web page software capabilities related to project needs. He recognized that this learning was a necessary step and specifically asked for help; consequently, he spent the time necessary. The school principal had arranged for released time amounting to one period per day with the expectation that the teacher would in the future be a resource to other teachers who wished to integrate technology in their teaching. The team was also fortunate to have the assistance of a creative, technologically literate student teacher who was willing to try new methods in mathematics instruction and had volunteered to do her student teaching in the project classroom.

The university team members maintained regular contact with the teacher to problem solve, encourage, and offer suggestions on integration of content and technology. The teacher's learning projects were reviewed and tutoring given to the teacher as needed. During this time the technological boundaries of the presentation and Web page software were explored, and a feel for the time that would be needed by the students to create their instructional products was gained.

The teacher, acting as a "pioneer"–pressing on regardless of the problems encountered–began learning to use Web-authoring software and Web development methods. His experiences with the software and technology were based around the actual skills he would need to implement the project fully in the third quarter. The teacher was encouraged by the other team members to verbalize and problem solve as needed. As the teacher's technological expertise increased, so did that of the students as they designed simple projects to teach mathematical concepts using PowerPoint. In all of these experiences, the university team members worked with the teacher for many hours beyond the four hours of scheduled weekly contact. Support and instruction were provided as requested to both the teacher and students in Class A. Along with the geometry, the students in Class A were taught cooperative learning skills to enable them to collaborate effectively in producing presentations.

During the third quarter the project proper commenced. The teacher began teaching each class as planned (see Table 1). Class A produced learning materials in PowerPoint and Claris Home Page, and Class B used these materials while Class C continued in the traditional instruction based on text and lecture. A rotating arrangement of the three topics to be covered (lines, angles, circles) was implemented to enable Class A to produce presentations for angles and circles which could then be used by Class B. Classes A and B were taught the topic of lines by the

TABLE 1. Order and Method of Topics Taught to Each Class During the Third Quarter

	1st Topic	2nd Topic	3rd Topic
Class A	Angles	Circles	Lines
	Produce materials	Produce materials	Traditional
Class B	Lines	Angles	Circles
	Traditional	Use materials	Use materials
Class C	Lines	Angles	Circles
	Traditional	Traditional	Traditional

traditional text and lecture method. Class C was taught by the traditional text and lecture method on all three topics.

This arrangement of topics across the three classes enabled all three topics to be taught and completed within the quarter. A teacher-constructed content test was given to the students in each class upon the completion of a topic.

STRUGGLES, CONCERNS, AND SOME SUCCESSES

Throughout the project, the teacher struggled with logistics and with the technology learning curve as well as the integration process. The students mastered the technology learning curve with a reasonable degree of success. The support team worked diligently to help resolve equipment problems and instructional concerns as they arose; they also assisted in the classroom with students as needed. However, numerous problems arose throughout the project.

Quarter 1: If Things Can Go Wrong, They Will

Logistics problems seem to be common when implementing the use of technology, and this project was certainly no exception. Internal network wiring and computer purchase delays were two of the concerns that were unable to be resolved. Planned phone lines were not installed to the classroom for Internet connections. Moreover, wiring connecting the geometry classroom to the existing computer lab and hence to the modem in the lab could not be run; thus multiple Internet connections were not available. Simultaneously, shipping problems prevented the timely arrival of hardware. To overcome these delays and technical problems, the teacher rotated student use of the two existing classroom computers so that groups could continue to try out their ideas and use the software tools. This internal rotation facilitated the process of transferring student practice ideas to electronic media and allowed the preliminary learning of PowerPoint. The students in Class A at this stage mirrored the simple technology tasks that the teacher had completed to increase his own knowledge.

Quarter 2: All Hands Needed on Deck!

The teacher's shift from traditional teaching based on text and lecture to a more collaborative method in Class A was well under way, a move that appeared to be well received by students. The presentation and Web page software learning process, however, took much longer than anticipated. Consequently, the university team members became directly involved in the teacher's classroom as technological problem solvers and participants. Direct tutoring of the teacher by the school technology director on software use was increased at the teacher's request. The teacher indicated that, overall, he had adequate support to continue his efforts.

Upon the eventual arrival during Quarter 2 of the three extra computers as well as the needed software, the computers were installed in the classroom, using technical assistance from the university. Students in the "production class" (Class A) worked on their projects using Claris Home Page and saved them to a common Zip disk for later editing. This temporary storage device enabled the students in Class B to access the complete project in order to learn the angles and circles material from the student-generated presentations. Students could access the computers for tutorials on the student-generated materials from the production class, while a Web "look alike" feel was attempted, an effort to simulate the Web-based format that had been envisioned at the start of the project.

Quarter 3: So Much to Do, So Little Time

The slowness of materials production was a major issue during Quarter 3. As the project progressed, the three classes began to drift out of sequence. Classes A and B were being left behind by Class C, and the sequence of rotation did not occur at the pace envisioned. Nevertheless, the teacher, seeing the benefits, became more excited and less concerned about the difference in content timing and coverage. In retrospect, a simple solution to this problem could have been from the very start to have had all classes using the technology-integrated pedagogies as implemented in Classes A and B. Presentations on independent topics could have been produced in each class, and then all of the presentations could have been rotated easily across all classes. In this scenario, at the end of the project all classes would have been exposed to all content but would have learned different topics with different teaching methodologies.

Class A required an initial reduction in the course content as defined by the textbook to make room for the software presentation and Web page production that had to be completed. Time was needed to let the students explore, develop ideas, and practice new skills using the geometry content as a base. The students in Class A were able to determine that some topics found in the teacher's curriculum could be eliminated or reduced in scope without compromising the content to be learned as defined by the state guidelines (Hawai'i Department of Education, 2004). The teacher willingly allowed the other project team members to discuss content coverage and make recommendations, yet he still needed to be reassured by an authoritative source that a change in his curriculum coverage was a choice he had the power to make. The state curriculum standards were a powerful legal base to be reassured by, as the Hawai'i standards incorporated technology requirements. Furthermore, the NCTM *Standards* (NCTM, 2000) also recommend technology implementation in mathematics. Hence, the teacher felt some justification in reducing scope to allow the adjustments necessary for technology-integrated, standards-based instruction. Recognition of the difficulty of this mental action is vital to full success in introducing standards-based education into a regular working classroom.

A major challenge in switching to a standards-based pedagogy is the necessity to drop or reduce components of the curriculum that are traditionally considered important but are not currently found in the state guidelines. The dynamics of making the paradigm shift from a traditional content-based curriculum to a standards-based educational paradigm is an issue of confusion and concern to teachers. The teacher-based questions of "how much content," "which content," "how do we teach and assess it," and "why do we actually need to make the change in the first place" are relevant concerns. For example, the Hawai'i State Content and Performance Standards (2004) for mathematics states, "Students analyze properties of objects and relationships among the properties" (p. 10). A subsection of this guideline reads, "Use logical reasoning to create and defend valid geometric conjectures." Mathematics teachers often interpret this requirement to mean the use of geometric theorems and planar rules as methods of developing competency in the use of geometric logic. For many years the teacher in this study had taught planar geometry using theorems and rules. Because of the considerable number of theorems and rules, this approach dominates a section of the curriculum. Nowhere in the standard, however, is the requirement that all the theorems or rules be taught, but rather only enough to demonstrate that the students can use "logical reasoning to create and defend valid geometric conjectures" (p. 11). In fact, one might argue that the use of theorem-based proofs is not required at all, and other suitable content in geometry might serve the same purpose.

The teacher in this project needed to make a critical decision as to which content could be safely omitted or altered in order to make space in the curriculum for innovative teaching methods that would address the state's standards-based outcomes. This decision was initially a dilemma for this teacher, since he had difficulty in letting go of traditional content. Happily, his unwillingness to compromise the project gave him the motivation to alter his teaching paradigm.

Quarter 4: Did the Students Learn the Content?

Classes A and B were taught the topic of lines by the traditional text and lecture method; Class C was taught by the traditional text and lecture method for all three topics.

(See Table 1 for the order of topics for each group.) Class A, which produced materials, and Class B, which used the materials produced by Class A, required the associated software instruction. Thus both groups received less teacher instruction in geometry during the third quarter than did Class C, with Class A receiving the least teacher instruction. Nevertheless, students in the three classes were given the same teacher-generated content tests at the end of their study of each of the topics. The results are shown in Table 2.

Interestingly, students across groups had numerically higher end-of-unit test scores for the topics of lines and circles, scores that were much more acceptable to the teacher, than for the topic of angles. Although mean scores for angles were at the D+ or C level, no satisfying explanation could be proffered for this lack of mastery regardless of method used.

TABLE 2. Percentage Correct on the Teacher Generated Geometry End-of-Unit Test

	Class A	Class B	Class C
Lines	89.2 (TI)	79.5 (TI)	80.8 (TI)
Angles	66.3 (PM)	72.5 (UM)	69.2 (TI)
Circles	82.9 (PM)	91.5 (UM)	77.5 (TI)

Note: TI = Traditional Instruction; PM = Produces Materials; UM = Uses Materials.

Conflicting Demands and a Paradigm Shift

As the project progressed, it became obvious that the teacher was having difficulty in switching between the traditional teaching method and the technology-integrated approach. Altering his teaching methodology on a favorite mathematics topic, especially when he had taught this way for many years, created a degree of stress based on his uncertainty regarding the "quality" of the mathematics education he was providing. The authors contend that this necessary shift in teaching methodology is one of the central challenges to the introduction of alternative teaching strategies when coupled with standards-based implementation. This teacher was not convinced that a pedagogical change of this magnitude would produce learning equal to his more traditional teaching methods. Based partially on his own recent experiences in learning the new technology and the software involved, his perception was that the added time needed to use the technology would decrease the learning of the students and actually have a negative impact on their attitudes toward this subject.

The authors were convinced that a technology-integrated pedagogy would not negatively affect the attitude of students (Turman & Schrodt, 2005). For a competent teacher with a long history of teaching success in mathematics, however, the risks, worth, and confidence in the changing paradigm were of great concern, hence the project design including three types of pedagogy. For many teachers, the perceived potential risks of integrating technology might even outweigh the effort to make the change (Qing, 2005). For a teacher contemplating technology integration, this fear of paradigm change relates directly to the time and effort needed verses benefits obtained if these changes are to be sustained over time, and hence the need for careful mentoring.

Toward the end of the project, the teacher was struggling with the temptation to supplement Class A and Class B with brief but intense regular traditional instruction in an effort to keep the classes synchronized in what they were doing. This ongoing struggle typifies the response of traditional teachers as they attempt to achieve results matching state expectations using standards-based instructional methods (Tiu, Gugliemi, & Wanton, 2002).

As this university partnership has shown, external support for teacher change is important. In this case, it provided scaffolding needed during each stage of development as the teacher moved through the technology integration process. Additionally helpful was the availability of a technology literate student teacher to share in some of the project load. While little has been said about the presence of the student teacher, many potential technology difficulties were overcome with her help on a daily basis. Well-prepared student teachers have subject competence and knowledge of good teaching practices. They are both learners and helpers, and therefore can give and receive in partnership with the supervising teacher (Tiu, Gugliemi, & Wanton, 2002). The cooperating teachers enhance this partnership as they use their own teaching experience to determine content needs, potential problems, and overall lesson flow. At the same time they receive practical help from the student teacher with teaching responsibilities, planning, implementation, and discussion related to the change process.

As a direct result of this project, this teacher subsequently became the "faculty technology integration advisor." Another mathematics teacher in the high school requested more computers and an outline of the project. Her intention was to follow the project path, taking care to avoid the pitfalls. Note should be made that she began this learning curve substantially more technologically prepared in her teaching methods than is usual, in contrast to our more traditionally based teacher. This difference in attitude and skill development may make a huge reduction in the level of outside support needed for a similar project in her class. The positive ripple effect of a project is a potential outcome of any effort in the school. Overall, however, teachers are likely to struggle with paradigm shifts of this magnitude, and careful consideration needs to be given by the director of curriculum to the actual problems and attitudes teachers may have.

RECOMMENDATIONS

Professional development experiences in which teachers are "taught what to do" in integrating technology will not mean that they can actually accomplish the tasks required. Instead, carefully supported self-paced models should be used as the teachers themselves create and implement their own development programs (Dede, 1998; Sandholtz, 2001). This project has demonstrated that, when teachers are asked to deal with the shift to standards-based teaching, being asked simultaneously to integrate a bewildering array of technology to support this new direction greatly compounds their paradigm problems. Over time, these conflicting issues may well dissipate as standards-based education becomes more firmly practiced in classrooms in general and the use of technology becomes more widespread.

The movement of a teacher from traditional pedagogy based on text and lecture, built on years of textbook use, to a standards-based pedagogy using innovative integrated-technology may be too large a paradigm shift to be accomplished at one time, regardless of the degree of willingness. Based on the experiences and results of this project, the authors suggest that the following recommendations, which are not necessarily considered to be sequential or independent, be implemented.

1. Introduce state curriculum standards to the teacher, and have the teacher clarify the outcomes that the students must reach to be competent at each standard.
2. Evaluate the current curriculum and determine which material needs to be included, altered, or left out to meet the competency measures.
3. Determine the necessary teaching techniques, regardless of what they might be, to implement the curriculum and skills that have been identified.
4. Identify skills that both teacher and students need to learn in order to implement a technology-supported standards-based program.
5. Related to items 1 to 4, selectively integrate technology use into the teaching pedagogy. This process should help the teacher grasp what needs to be done in a standards-based classroom and have a basic curriculum for the year outlined. The individual lessons could be developed as the process is implemented, as could details of the assessments.
6. Identify the technology to be implemented and the skills that will be used with this implementation. The purchase and installation of technology should be concluded before the teacher begins to integrate the use of the technology into his or her teaching. This

planning will help solve problems created by delivery delays or installation problems that might interfere with the overall teaching process.

7. Start small and work up to the full program. Try out small chunks and refine teaching methods gradually, allowing traditional teaching to continue to be the mainstay in the first year of the change project. More and more time should be spent working with technology-based projects in mathematics as the year progresses (Tiu, Gugliemi, & Wanton, 2002).
8. Above all, recognize that there will be problems, and have a strong support group with whom teachers can discuss and solve problems. This support is fundamental, as teachers may feel overwhelmed by the simultaneous tasks that are presented when viewed within the regular day-to-day teaching. A teacher who is moving through the stages of technology integration needs guidance from someone who knows the stages and can provide the type of support needed for each. The day-to-day pressure to maintain the fast pace of the classroom, handle multiple tasks, and generally be prepared to teach may interfere with the acquisition of technology-related skills and knowledge by the teacher.

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