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How Technology Integration in Mathematics and Science Teaching Can Occur: The role of the maverick teacher

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Helping teachers to change practices by adopting new tools and pedagogical approaches is of interest to a wide range of educational researchers and practitioners. This article describes a teacher, Ms. Hogan, who is an early adopter of a technological innovation: the authoring tool Squeak. We analyze email messages from Ms. Hogan applying Rogers' model for the diffusion of innovation. We find that this maverick teacher was quickly persuaded and decided to adopt the tool even before her knowledge of the tool was complete. The tool met the needs of this teacher in her context but in order for her experience to be more general, the authors hypothesize that materials must be created to make the tool relevant to non-maverick teachers.

Introduction

Recent reform movements within the United States call for an increased awareness of both mathematical and scientific literacy (National Research Council (NRC), 1996; Steen, 2001). This reform movement is not restricted to the United States—similar reform efforts have been seen in other parts of the world (Goodrum, Hackling, & Rennie, 2001; Millar & Osborne, 1998). Key in current conceptualizations of modern mathematical and scientific literacy is the role of technology as a tool to enable literacy and understanding as well as inquiry.

To help facilitate the objectives called for in these reforms, national organizations worldwide have established standards that identify key learning goals and processes that students should understand for basic quantitative and scientific literacy. The

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different documents emphasize the teaching of science through inquiry and situated within the context of the real world and the understanding of the content that can come through engaging in a range of scientific practices (AAAS, 1993; NRC, 1996). They also call for an understanding of the role of technology in these practices and the use and exploration of technology tools by students in classrooms. In these documents, as well as the more localized regional documents, teachers are called upon to modify their teaching practices and to engage in more student-centered instruction using a range of strategies. One such strategy is to use computer-based tools. A critical issue, then, is how to incorporate the new technologies within the reform frameworks.

A Vignette of a Maverick Teacher

In this paper, we present the story of a teacher, Ms. Hogan, who adopted a new technology. She did this as part of a project addressing teaching practice and student learning. The project is an ongoing collaboration between a university and a local school district. Through this case study, a vignette of a maverick teacher, we hope to give a sense of how professional growth can be enhanced through the adoption of an innovative tool.

We present a story of change in a single individual mediated through a collaborative partnership. This partnership allowed her to participate in reflective practice and thoughtful professional development, which impacted her growth as a teacher (Borko, 2004; Richardson & Placier, 2001). While we acknowledge that this is the story of a single teacher, we do believe this story is worth sharing so that a more detailed picture of early adopters and teacher leaders can be created. Such a story will show how teaching changed and aligned with the new frameworks. As Dukes (1965) has claimed, a single instance (N=1) can be important in cases when opportunities for observing a class of events are limited. We believe that our setting fits his description of an important single instance. We use the specific example of the maverick teacher to illustrate the challenges of adoption and to raise questions on the adoption of the technology by other teachers.

To move from the individual to the group, we use Rogers' (2003) notion of "relative advantage". We ask, what is the relative advantage for a maverick teacher to adopt and use a new technology—why does the teacher expand the energy necessary to learn and use a new technology tool? The term "relative advantage" describes the ratio of expected benefits to the costs of adopting an innovation. We would like to be able to expand our studies to examine how the relative advantage of the early adopters compares with the advantage that is seen with other teachers or groups of teachers who do not fit the criteria of a maverick teacher. In order to carry out this second part of the study, we need to document the relative advantage that an early adopter experiences. We feel that it is important to study such cases—school districts often struggle with meaningful technology integration but when such technology integration is accomplished, increased student learning and engagement occurs (Honey, McMillan, & Carrig, 1999). The role and experiences of the maverick teacher in this process help us understand both why and how teachers learn to accommodate and use a new technology. Their story also helps us understand issues around general dissemination and use of these tools by other teachers.

Who are the Mavericks?

Not all teachers are both willing and able to align their teaching with the new teaching standards in mathematics and science, nor with the integration of technology. While many do not embrace reform, there is one group of teachers that consistently embraces new methods and strategies to support their students as they engage in independent inquiry. These teachers have been labeled "maverick" teachers or "early adopters" (Jacobsen, 2000; Rogers, 2003). These are the teachers who are willing to try new strategies, curriculum, tools, and technology before their colleagues. In reviewing the literature, we found very few case studies that describe these maverick teachers and the characteristics that allow them to succeed in the changing environment. As a field, we do not know why these teachers choose to use new technologies or to try new teaching strategies. As participants in the project that Ms. Hogan was part of, we are interested in understanding more about what drives this type of teacher and how she changed through the use of the tool.

Key Questions

We are interested in adding to the literature with our study of an early adopter as she explored and developed her own expertise around an object orientated programming application, Squeak. Our key questions are:

- Why was the tool selected over others?
- What are the characteristics of the process of her adoption of the tool?
- How did it influence Ms. Hogan's growth as a teacher?

In the case we report here, Squeak is replacing more traditional ways of teaching. As such, it required new ways of learning and problem solving—how did Ms. Hogan acquire these and how did she implement them as she used the new technology tool with her students?

Describing the Tool

The technology focus of this article is the multimedia authoring tool, Squeak. Squeak is object-oriented and open-source. It allows users to make drawings, save them as objects, create scripts to animate the objects, and have them interact. Squeak provides opportunities for simulation and visualization. The user-friendly interface masks the sophisticated underlying program, which allows "entry" for even very young (e.g., kindergarten) students. Students come away with an elementary grasp of programming and can develop powerful thinking and problem-solving skills. Ms. Hogan found this tool as our team made attempts to integrate several other visualization tools into our work with schools. We were searching for a tool to incorporate into a range of classrooms that could be used to model key scientific and mathematical concepts in meaningful ways. Soon after Ms. Hogan found Squeak, we dropped all efforts on the other tools in order to focus on this one.

Literature Review

Early adopters are often described as motivated, risk takers, or teachers who are confident with their teaching and content, yet early adopters have different characteristics. What these characteristics are is not clearly articulated in the literature. Rogers (2003, p. 264) describes early adopters as those with "the greatest degree of opinion leadership in most systems. Potential adopters look to early adopters for advice and information about an innovation." Jacobsen (2000) accepts the categories of Rogers for describing diffusion of innovation in general terms, but emphasizes the importance of the individual cases with their unique stories. In addition to describing such a maverick teacher, we document how she introduced Squeak to her local teaching community and the resulting changes that occurred.

Issues Surrounding the Use of Technology in Schools

There has been considerable skepticism with regard to technology efficacy in schools (Cuban, 1986, 2001; Noble, 1998; Oppenheimer, 1997). Particularly problematic are computers that are used for drill and practice (Manoucherhri, 1999). Nonetheless, advocates for the use of technology in the classroom have long believed there are effective ways to use digital technologies in the classroom (Papert, 1980, 1993, 2002; Tapscott, 1998). Computers can be used to teach explicit skills and knowledge or they can be used to encourage students to explore options and pursue individual learning goals in ways that would not be possible without the use of technology (Bereiter & Scardamalia, 1992). These two ways, skills vs. individual goals, can be viewed as two points on a continuum with a wide range of options between them. Both of these ways of thinking about computers can be used in a more reform-oriented way of teaching that is more student-centered.

One report, *Does it compute?* (Wenglinsky, 1998) illustrates how the crucial role of teacher professional development can impact the use of new technologies and new teaching strategies. This study found that in order to show positive gains in academic achievement, it is not only the professional development that is important but also the way computers are used. For technology to have a significant impact, it must go beyond routine, drill-and-practice activities. Developing teachers' knowledge in the effective use of technology is crucial for adoptions to be successful and enduring.

Components of Rogers' Diffusion Model

Rogers' (2003) diffusion of innovations model encompasses five phases that adopters encounter as they interact with a particular innovation: knowledge; persuasion;

decision; implementation; and confirmation of all of these issues. We use this model to identify issues that need to be addressed in order to understand why a particular tool might or might not be adopted. We acknowledge that we are constricting our framework to a single individual and as such we are focusing on the adoption rather than the diffusion. We do believe that Rogers' framework is applicable in this analysis.

Connecting Professional Development with Teacher Needs

In recent literature, there has been increased documentation of alignment of professional development to the teacher's actual needs and context (Borko, 2004; Fishman, Marx, Best, & Tal, 2003; Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003). This has come with the recognition that professional development is crucial for the success of standards-based reform as called for in the national documents (AASS, 1993; NCTM, 2000; NRC, 1996) as well as in the recently passed No Child Left Behind legislation in the United States.

We are interested in understanding the use of technology in the schools, since this is often seen as a cross-cutting area for professional development. In understanding what mobilizes and enables a maverick teacher to adopt a new technology, we begin to understand issues surrounding adoption of technology, including the need for specific professional development.

Methods

Setting

Ms. Hogan works with our project in a Midwestern university town. We are a collaborative project between a Research 1 University, a local school district, and several community organizations. Our project is currently active in 18 local institutions, schools, public libraries, community college libraries, university courses, and outreach programs as well as the local Boys and Girls club.

This vignette focuses on a maverick teacher, Ms. Hogan (a pseudonym). Ms. Hogan taught in the school as a music teacher for 30 years before taking early retirement. Subsequent to her retirement, she returned to the school as the enrichment teacher. In this capacity, she teaches small groups of students from 11 2nd–5th-grade classes. Each classroom teacher sends a small number of students who will benefit from exploring curriculum topics in a non-traditional way. Students are expected to maintain good grades and to make up class work they miss while out of the room for enrichment. Ms. Hogan's main focus is geometry and it has proven to be a rich vein of interesting topics for children. Class meets for 40 min once a week. She has no classroom and works in the hallway of the second floor. Here she has four tables at which students can work, and four computers, with which students can explore a range of applications. Ms. Hogan is not certified in mathematics or science but is interested in these areas and structures her enrichment activities to incorporate as much mathematics and science as possible. She is an extremely confident and capable teacher while working with young children.

The Squeak Application

Squeak is a platform independent "media rich authoring tool" that allows an easy entrance into the interesting world of programming (Viewpoints Research Institute Inc., 2006). The multiple platform compatibility was important to us, since a project created on one system can be opened and run on almost any computer. A project started at home can be continued at school. In addition, students can use Squeak throughout their K-12 years—as they develop their Squeak programming skills, they can program more and more complex models appropriate to their curriculum.

As Squeak assembles scripts from click and drag tiles, it allows beginners to focus on the logic of their ideas rather than syntax. In typed programming languages an incorrectly placed space or punctuation mark causes the script to fail. Click and drag tiles eliminate that kind of problem for the beginner. They can test ideas rather than typing skills. Squeak scripts can be changed while they are running by adding or removing script tiles or by changing a number value in a script. Effects are immediate. Examples of Squeak projects created by Ms. Hogan's students were posted to the SqueakCMI superswiki (available through the SqueakCMI.org website).

Data Sources

Our main data sources are email messages with Ms. Hogan and other electronic artifacts from a 20-month period of the project. We identified Ms. Hogan as a maverick teacher and early adopter soon after her discovery of Squeak. We had been searching for appropriate modeling and visualization tools to be used in elementary classrooms that would help address key science and mathematics standards as articulated by the national, state, and local documents in the United States. At a professional development conference on modeling and visualization tools at the 2003 SuperComputing Conference, our group was exposed to a variety of proprietary tools for integrating visualization technologies into the classroom. Most of these tools, such as Mathematica, Fathom, Agent Sheets, and Interactive Physics, are appropriate for integration into the curriculum for secondary level students or higher. Ms. Hogan was interested in tools for elementary school teachers and students and realized that the tools that she had worked with were inappropriate. Nonetheless, she believed as she continues to believe in the importance of modeling and visualization in the classroom.

One day in February 2004, as project members struggled to find ways to put the tools they knew into use and retool them for elementary school, Ms. Hogan sent the group a note stating:

> I learned Squeak today. I downloaded the software, it is free, it has good tutorials and it is fun. Could I hear some opinions on whether or not it would be a good place for the [school name removed] kids to start playing around. There are rules, there are xy

> coordinates, and there is creativity. The software will string together commands about objects in the world created on the screen and has them move like a cartoon.

At this modest announcement, the floodgates of inquiry were opened. This was the first of approximately 700 messages sent over the next 20 months that included a discussion of Squeak. We report on the analysis of emails collected from February 2004 to October 2005. Emails from this period were selected as the teacher was critically examining her progress during this timeframe.

Over the 20 months of the project, Ms. Hogan has arranged and led over 100 presentations and workshops using Squeak and has had the program installed on the computers at 18 local institutions, schools, public libraries, community college libraries, and boys and girls club computers, and university computers. Through Ms. Hogan, our group was connected to the network of Squeak users and developers and hundreds of students and teachers in the area have learned and are using the tool. Our records of the largely electronic exchanges and the developments that this team member led are our most important data sources. She created a series of notebooks in which she kept detailed information about how the project was progressing. In these notebooks, her own learning trajectory could be mapped and analyzed.

Data Analysis

Data was analyzed for themes connected to the model Rogers (2003) presented regarding "diffusion of innovations". We examined a subset of Ms. Hogan's emails for evidence of knowledge, persuasion, decision, implementation, and confirmation, all of which are key steps in Rogers' innovation–decision process. In our analysis, we began to see trends across the data that could be organized around these categories. In each of these categories, we saw evidence of teacher change and possible implications for technology adoption and use and future professional development. Our codes for the five phases of Roger's innovation-decision process (p. 169) included:

- *Knowledge:* Understanding the application and what the tool could do for the teacher and for the students. We include here evidence of developing discipline math and science knowledge as well.
- *Persuasion:* Expressed beliefs about what the tool would allow students to do and how it would impact the current teaching practices. Evidence of beliefs about how the tool would change the learning of the students is included in this code.
- *Decision:* Description of factors influencing the decision to adopt the tool or not within the teaching of the case teacher as well as a desire to have additional teachers use the tool.
- *Implementation:* Description or indication of instructional strategies that took into account the strengths/weaknesses of the tool.
- *Confirmation*: Advantages and disadvantages to the adoptions or implementation of the tool. Indication of a desire to continue the use of the tool was included in this code.

- We present our findings below and illustrate them with excerpts from the emails written by the teacher, Ms. Hogan.

Findings

In examining our data, we identified features of a maverick teacher engaging in the phases of Roger's innovation–decision process. This teacher is a highly motivated veteran teacher who was willing to try new and possibly unorthodox approaches to teaching. In this study, she was the participant who identified Squeak as a possible tool to use with her students to teach them new approaches to problem solving and technology literacy. This identification and subsequent belief in the tool was crucial to the success of the project. We believe that this willingness to explore and develop new skills in both teaching and learning is a crucial maverick characteristic.

As we engaged in our analysis of the adoption of this tool by Ms. Hogan, we did not see the phases Roger identified as distinct phases that the teacher had to pass from one to another. Rather, we saw overlap of each category during the adoption phase of the tool. For example, we did not find evidence that Ms. Hogan needed to fully understand the tool before making a decision to use the tool in her own classroom and to try and convince additional teachers to use the tool as well. Thus, she was persuaded before her knowledge was complete.

Knowledge

Knowledge of the tool as well as developing content knowledge was coded for in this category . Ms. Hogan has continued to develop in this area over the entire course of the project. This phase of the innovation–diffusion model has been one that has seen the greatest amount of change. Initially Ms. Hogan focused on the application and how she perceived her understanding of the application. This belief of understanding the tool simply by working with the tool for one day has shifted to a more complex and detailed understanding of the tool and the realization that she will not master the tool for an extended period of time. In understanding more about the tool, Ms. Hogan also began to develop a deeper understanding of the math that she was doing, as is illustrated in the two email extracts below.

> I did some early experiments (months ago) to see if the order of script tiles for forward and turn mattered about the place … Knowing that the scripts tiles run in order top to bottom made me realize I could do the math problem using script tiles in the order that I wanted that math operations to happen. That is they didn't have to be done all in one line of script.

And

> Previous Squeak projects which related the heading of a car to the heading of a wheel and tying the turn of a car to the turn of a wheel are experiments I have tried many times. I think realizing that the two things could be joined and then control one with the other was one stage toward solving this problem. Dropping a tile on a tile … Another was learning to make and add a variable speed to a car's forward and then adding a

> random number from the Supplies flap. Making variables still feels a bit like conjuring to me. This is more math than I have done, needed to do or wanted to do in a long time.

But even here, Ms. Hogan is articulating that she realizes that the tool has more to offer her and that she will continue to learn about both the tool and the content that has become the context of her use of the tool. Ms. Hogan has recently arranged "private" tutoring sessions with a university computer science professor to develop her understanding of the tool to a deeper level. She is becoming more convinced that the tool is useful for her students and is a tool that she needs to continue to learn so that she can teach not only her students how to use the tool, but also additional teachers.

Persuasion and Decision

Ms. Hogan's recognition of Squeak as the appropriate tool for our efforts was almost immediate. In looking at Ms. Hogan's emails we can see why. She had a strong belief that the tool could change the learning of her students and that it had impacted what she was learning as well. This self-reflection is evident in the email below.

> The interest for me is in exploring uses of Squeak. For example I do not really care about the ant/pheromone project I did months ago but I did like the fact that I had the tools to model what happens. It was challenging to think about how I would show something like that. It is not that I am fascinated with the topic of ants. The same was true for the paramecium project.

Ms. Hogan has experimented with importing pictures and music into Squeak as well as recording her own music to see how she can include a range of different materials into the tool. In addition to her own experimentation, she has had her students record different sounds to include in their models as well as images that they have taken using digital cameras.

Ms. Hogan's confidence in the importance of the tool is extended by her efforts to inform others. She has been the primary presenter at a dozen national and state conferences, in which she talked to experienced teachers or researchers about the tool and her belief in the value of using it. While her confidence in her teaching was strong, her confidence in the depth of her knowledge was weaker. In an email that she sent to the rest of the project leaders, she expressed her frustration about not knowing enough to respond clearly to a teacher's questions about how the tool might benefit his students. This frustration and resolution is shown in the excerpt below.

> I worked with one man from New York State who is a middle school teacher with more energy than any one person ought to be allowed … He wore me out with questions and finally found some I could not answer. I got aggravated with myself for worrying about the fact that I couldn't answer every question so on the drive back to [name of town removed] I enjoyed the conversation in my head between the one who said "good job", the one who said "why didn't you know that answer" and

> the Alfred E. Newman persona who said, "What, me worry?" We had quite a conversation!

Nonetheless, the tool has dominated Ms. Hogan's instruction. Her enrichment teaching has changed to focus on the use of only this one technology tool. Initially, Ms. Hogan used multiple computer applications that she believed helped her students model different situations. But as her Squeak expertise developed, she began to stress these other applications less and less. She has not totally abandoned other technology tools, but instead has chosen to focus on having her students learn one tool in greater depth. She continued to have her students use different tools, such as digital cameras and microphones, that could be integrated into Squeak projects.

Implementation

Issues around implementation focused on how Ms. Hogan could improve her own use of Squeak in her instruction. This is reflected in an email that she wrote, in which she discussed the differences between her own use of Squeak and her students' use of the tool.

> I have been puzzled about how slow I have been to learn Squeak when I see how quickly the kids learn it. Part of the reason for their speed is that we are good teachers and make smooth the path that was rocky for us. Another part is that they are so accustomed to seeing game/cartoon images that they have a pool of ideas they want to try once they see a Squeak tile that lets them get closer to what they want. This might be "scaffolding".

Here she is pulling on students' other funds of knowledge and relating it to the work that they are doing in school.

In addition to reflecting on how she should be using the tool in her teaching, she took time to visit other teachers' classrooms to see how they used Squeak. In the email below, she is talking to a computer scientist who was teaching a summer program for at-risk girls and who had elected to use Squeak.

> I got to see how you approach it and wish like anything you would go through it again with me so I can take notes. From the very start you had fundamental principles of programming at the forefront. Too bad I don't know any.

Ms. Hogan realized that Squeak would need additional instructional resources if it were to be adopted as a tool in a regular classroom. In order to help teachers implement Squeak in their classroom, Ms. Hogan began to develop ideas for additional instructional supports. Below is one such idea that she is currently working on.

> Another resource we should consider using is film. AVI Classic is what I found but certainly didn't do any definitive research on it. Just looked, found, used. It certainly makes examples clear from the tile use point of view. It does nothing to help someone understand why. Why add a variable to a project? Why use a detailed watcher? Etc. So film won't do it alone but a library of minute waltzes might be handy.

The implementation process has been slower than she thought, but she has met with more success in the second year of the project. Perhaps this is because teachers are now seeing how their students are using Squeak in community organizations or in

Ms. Hogan's Enrichment program, as she has been encouraging her students to continue using Squeak in their regular classroom.

> I went ahead an offered to help the Enrichment teachers get a group started with Squeak this coming year. Call me crazy but I think only a few will take me up on the offer and I will be sure to manage it so it is a little of me. There were several who were already experimenting and some who were lost. But I had a feeling many of them were intrigued by the possibilities. Keeping in mind your dislike of the one-shot-workshop, I ventured into the future. This is where I thought we would be by October last year.
>
> In addition we are beginning to see evidence of students who learned Squeak in community programs using Squeak in their regular classroom.

Confirmation

In the confirmation phase of the diffusion–innovation model, Ms. Hogan has been articulate in voicing her views on the strengths of the application. Here she strongly indicates what she sees as value in the application and a desire to continue using it in specific situations.

> I see Squeak playing a role as a tool for expressing ideas from any number of disciplines. The developers label "a multimedia authoring tool" looms larger and larger in my mind as an accurate description of Squeak. It has allowed me to express ideas that I have no other tool for. The way I think when I am trying to write a script for a project has given me new strengths in analysis, spatial reasoning, patience and persistence, orderly and precise thinking. It has given me insights into how the effects are achieved when I see other models and visualizations. For example, when I see a weather map simulation of a high or low front moving across the country, I can see how I could show something similar in Squeak. Or, the little "help" messages that only appear in a program when a right mouse button is hovers or is clicked is the same as mouse down/show and hide in Squeak. This kind of understanding lessens the mysteries of what I am seeing all the time in the many hours I spend at the computer when I am not using Squeak.

Ms. Hogan has specific views on what she wants the application to do for her students and she clearly articulates where she believes this focus has its basis.

> My interest is much more in process than product or topic. Partly that may be because of my background in music. It is almost all process. The "product" in music is a performance but that is such a tiny proportion of the time a musician spends on a composition. When I am playing a piece of music I am not aware of the clock minutes and hours that are passing. Time is not suspended but rather transformed by the experience of playing the piece into becoming a world apart where time is only the time of the music. I think this same effect is felt in Squeak when you see children sitting and working hard for an hour and a half at a time or more if we would have let them … This sense of no time passing is common for anyone who has a deep interest in something.

Yet she realizes the constraints that she is working within and is willing to try and work within the system to show that Squeak is of value and should be used on a larger scale than it is.

> Shall we try to measure academic gains in verbal, math or non verbal achievement. I still think the Naglieri has the potential to do this. Can you order a sample copy from some

> resource on campus, ed psych, or shall I do some research into this? If not Naglieri, then something else. Barbara any ideas on this? There are skills and knowledge specific to Squeak (click and drag, objects, methods and properties and a working vocabulary of a some valuable words such as scale factor, angles, degrees, obtrudes, heading, positive, negative, Boolean, true, false, variables,) involved but also general skills in logical thinking and analysis. Not to mention the character building aspects of starting all over because "publish it'"froze half way through. [name withheld] has pointed out the advantages she sees that let children take more risks with ideas than they might with paper and pencil trials. Student's Squeak portfolios would be another way to show what children achieve.

Conclusions and Implications

What we have seen in our exploration of the adoption in the case of Ms. Hogan is that the early stages of the model have been compressed. Because the tool fit a perceived need, the decision, persuasion, and implementation phases came rapidly and were prior to a very complete sense of knowledge. Indeed, Ms. Hogan is still learning many of the aspects of the tool and, as she learns more, she is affirmed in her initial decision to use it. For her, the relative advantage of using Squeak was obvious. It provided immediate success in programming and has been expandable to new projects as her knowledge has grown.

While we see that Ms. Hogan has adopted the innovation for herself, and that the artifacts of her emails indicate that her rapid progress through the five stages of the Rogers' model as she adopted the tool for use in her teaching, this model has yet to be generalized to a larger group.

For other teachers, the adoption could be much slower. We believe that the delay of adoption or spread of innovation is caused mainly by the lack of immediate applicability for most teachers. In a recent workshop in which a computer scientist presented Squeak to a group of middle and high school teachers, the teachers were asked if they would use this tool in their classroom. After a silence, one said, "No, it would take too much time to learn." In other words, that teacher did not see the relative advantage for the time involved in learning the tool. For Ms. Hogan, who was willing to devote many hours to exploring the program, the pay-off was well worth the effort, as is illustrated in her many emails and continued use of the tool.

The challenge for our project is to make this innovation relevant to the many teachers who are immersed in the day-to-day demands of mathematics and science lesson plans, and who are looking for a tool that requires little preparation. It remains an open question, and a future direction of research for the authors, to find out if larger numbers of teachers will respond to Squeak.

References

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy.* New York: Oxford University Press.

Bereiter, C., & Scardamalia, M., (1992). Cognition and curriculum. In Philip Jackson (Ed.), *Handbook of research on curriculum,* (pp. 517–542). New York: Macmillan.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher, 33*(8), 3–15.
Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920.* New York: Teachers College Press.
Cuban, L. (2001). *Oversold and underused computers in the classroom.* Cambridge, MA: Harvard University Press.
Dukes, W. F. (1965). N = 1. *Psychological Bulletin, 64*(1), 74–79.
Fishman, B., Marx, R., Best, S., & Tal, R., (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*(6), 643–658.
Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report prepared for the Department of Education, Training and Youth Affairs.* Canberra: DETYA, Commonwealth Department of Education, Training and Youth Affairs. Retrieved February 20, 2006, from http://www.detya.gov.au/schools/Publications/2001/science/index.htm
Honey, M., McMillan, K., & Carrig, F. (1999, July). *Perspectives on technology and education research: Lessons from the past and present.* Paper presented at the The Secretary's Conference on Educational Technology, Washington, DC.
Jacobsen, M. (2000, March). *Excellent teaching and early adopters of instructional technology.* Paper presented at the ED-MEDIA 2000: World Conference on Educational Multimedia/Hypermedia & Educational Telecommunication, Montreal, Quebec.
Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics.* (2nd ed.). Thousand Oaks, CA: Corwin Press.
Manoucherhri, A. (1999). Computers and school mathematics reform: Implications for mathematics teacher education. *Journal of Computers in Mathematics & Science Teaching, 18*(1), 31–48.
Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future.* London: Kings College, University of London.
National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: National Council of Teachers of Mathematics.
National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.
Noble, D. D. (1998). The regime of technology in education. In L. E. Beyer & M. W. Apple (Eds.), *The curriculum: Problems, politics, and possibilities* (pp. 267–283). Albany, NY: State University of New York Press.
Oppenheimer, T. (1997, July). *The computer delusion. The Atlantic Monthly,* 45–61.
Papert, S. (1980). *Mindstorms.* New York, NY: Basic Books.
Papert, S. (1993). *Obselete skill set: The 3 Rs. Wired, 1.* Retrieved February 22, 2006, from http://www.papert.org/articles/ObsoleteSkillSet.html
Papert, S. (2002). *Squeakers – Chapter 16.* In J. Shasky & B. MacBird (Eds.), Squeakers [DVD]. Muncie, IN: Ball State University.
Richardson, V., & Placier, P. (2001) Teacher change. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 905–950). Washington, DC: American Educational Research Association.
Rogers, E. M. (2003). *Diffusion of innovation* (5th ed.). New York: The Free Press.
Steen, L. A. (2001). Quantitative literacy. *Education Week on the Web, 21*(1), 58.
Tapscott, D. (1998). *Growing up digital: The rise of the net generation.* New York: McGraw-Hill.
Viewpoints Research Institute, Inc. (2006). Squeak [computer software]. Retrieved February 22, 2006, from http://squeakland.org/
Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics.* Princeton, NJ: Educational Testing Service (ETS). Retrieved February 20, 2006, from ftp://ftp.ets.org/pub/res/technolog.pdf