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DEVELOPMENT ARTICLE

A systems-based approach to technology integration using mentoring and communities of practice

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Abstract The purpose of this article is to present a systems-based mentoring model of technology integration that follows a research-based path. The model moves teachers through four specific stages of technology adoption toward using technology to support learning in more student-centered ways. The model describes how a mentor can negotiate the interplay of multiple barriers (time, beliefs, access, professional development, culture) on teachers who are learning to integrate technology and suggests a number of strategies for integrating technology, such as establishing a culture of technology integration, modeling technology use, and creating teacher leaders. Unlike previous mentoring approaches to integrating technology into the classroom, this model culminates with the establishment of a teacher-led community of practice that uses the resources currently available at a school to support and sustain the implementation of the system. Suggestions for implementing the model in a variety of K-12 and higher education settings are discussed.

Keywords Technology integration · Model of technology integration · Mentoring · Community of practice

The availability of computers with access to the Internet in today's public schools is steadily increasing. Wells and Lewis (2006) reported that the ratio of public school students to computers with Internet access has improved from 12.1:1 in 1998 to 3.8:1 in 2005. In many of today's classrooms, however, teachers primarily use that technology for tasks that fall outside the delivery of instruction (Hayes 2007; Zhao and Frank 2003; Wells and Lewis 2006). Zhao and Frank (2003) found that teachers across 19 different schools mainly used computer technology to address their immediate needs and in ways that did not place extra demands on their time, such as communicating with parents and colleagues. Wells and Lewis (2006) surveyed the technology coordinator at 1,012 schools and found that

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computers were predominantly used to access online assessments and assessment data. These uses of technology undoubtedly improve the workload of teachers, but are far from the student-centered approaches promoted in the literature.

Using technology to support learning in student-centered ways is important because there is evidence that these approaches can positively affect student performance (Abramovich 2006; Brown 2007; Lei and Zhao 2007; Machin et al. 2007). Lei and Zhao (2007) found that among 130 middle school students, those who used technology to manipulate data or to construct representations of their knowledge experienced an increase in grade-point average over the course of a year. This supports Forcier and Descy (2008) and Jonassen et al. (2008) who suggested that using technology in student-centered ways enhances curriculum, motivates students to learn, and improves student learning of subject-specific content. Their examples of student-centered practices include students working together to gather and process information, solve realistic problems and present knowledge in new and creative ways. If student-centered practices can lead to improved student performance, why are teachers primarily using technology for tasks that fall outside of their instruction?

Teachers may not be adopting student-centered approaches to technology integration because they lack the knowledge needed to do so. Teachers need to obtain basic technology skills before they can adopt student-centered practices with technology (Ertmer 2001; Hew and Brush 2007; Snoeyink and Ertmer 2001–2002; Zhao et al. 2002). Also, teachers need exposure to the pedagogy consistent with designing and conducting meaningful learning with technology (Bauer and Kenton 2005; Hughes 2004; Koehler and Mishra 2005; Waight and Abd-El-Khalick 2007). It makes intuitive sense that teachers who lack the skills or knowledge to teach with technology would chose not to do so in their own lessons.

Another reason why teachers may not be adopting student-centered approaches to technology integration is that they face a number of barriers that prevent them from doing so. These barriers are thoroughly summarized in prior literature (see Ertmer 1999; Franklin et al. 2001; Hew and Brush 2007; Hinson et al. 2006) and are presented below in terms of what teachers typically lack:

- *Time* to learn new technology and prepare instruction that integrates technology into the curriculum (Bauer and Kenton 2005; Cuban et al. 2001; Feist 2003).
- *Beliefs* that support the use of technology for teaching (Lim and Khine 2006; Norris et al. 2003; Zhao et al. 2002).
- *Access* to current and functional technology (hardware, software, Internet access, etc.) and to support (Bauer and Kenton 2005; Clark 2006; Norris et al. 2003).
- *Professional Development* that goes beyond skill building with technology such as mentoring, peer collaboration, and lesson design (Bradshaw 2002; Earle 2002; Koehler and Mishra 2005; Glazer et al. 2005).
- *Culture* that promotes technology use and the adoption of new teaching practices (Roschelle et al. 2001; Vanatta and Fordham 2004).

Managing these barriers to technology integration is complex. Researchers (Levin and Wadamy 2006, 2007; Snoeyink and Ertmer 2001–2002; Zhao et al. 2006) have found that teachers adopt technology at different rates depending on factors such as their beliefs about technology and their individual skills with technology. In addition, each barrier plays a role in the severity of the other barriers (Hew and Brush 2007; Hinson et al. 2006; Lim and Khine 2006; Zhao and Frank 2003). For example, Hew and Brush (2007) suggested that teachers' beliefs, knowledge, and skills could positively or negatively impact each other and the other barriers that teachers face. Zhao and Frank (2003) suggested that the process of technology integration is an evolutionary one, and that teacher's beliefs, pedagogy, and technology skills slowly build upon each other and co-evolve as technology is introduced and assimilated into the school culture.

A number of technology-integration models exist in the literature (Hinson et al. 2006; Friedrichsen et al. 2001; Whitehead et al. 2003), but none fully address the complexities that arise from the interplay of the barriers teachers face or the constant introduction of new technology into the classroom. For example, Hinson et al. (2006) recommended that professional development planners use their five-step model of technology integration: planning, preparation, instruction, refinement, and evaluation (Hinson et al. 2005). While their model presents a process for designing training, it does not address the sustained efforts needed to address the barriers that influence teachers' decisions to use technology, such as school culture and personal beliefs about teaching with technology.

To prepare teachers to integrate technology in more student-centered ways, a model of technology integration is needed that is robust to the many barriers that teachers face as they learn to use technology and align their beliefs with new instructional practices. The purpose of this article is to present a system-based model of technology integration that uses mentoring and communities of practice to support teachers as they develop the skills, pedagogy, and beliefs needed to integrate technology in a student-centered manner.

Mentoring in the context of technology integration

Mentoring has been found to overcome many of the common barriers to technology integration (Bullock 2004; Franklin et al. 2001; Gallagher 2000; Polselli 2002; Swan and Dixon 2006; Ward et al. 2002). Franklin et al. (2001) found that K-6 teachers who learned to integrate technology with a mentor more easily overcame barriers such as finding time to integrate technology, learning to troubleshoot problems with technology, and learning to integrate technology into an actual classroom setting. Polselli (2002) found that 139 teachers who received mentoring support reported improvements in comfort levels with technology, in self-perceived skills, and in the number of instances of technology integration in their practice. Gallagher (2000) found that elementary school teachers who received classroom-based training with technology felt more confident after the training and were likely to integrate technology into their teaching in the future.

Mentors provide teachers with just-in-time support while they integrate technology into lessons they are actually teaching (Bullock 2004; Lai et al. 2002; Whitfield and Latimer 2003). They present teachers with different models for teaching with technology (Ertmer 1999; Glazer et al. 2005; Lim and Khine 2006) and provide assistance that meets their specific needs (Swan et al. 2002). Swan et al. (2002) found that 175 teachers reported improved levels of confidence and creativity when they learned student-centered approaches to integrating technology in their own classrooms with the aid of a mentor. This translated into higher levels of motivation and self-efficacy for the students of the teachers in the project as well. It seems that mentoring has the potential to better meet the needs of the teachers learning to use technology to enhance learning and, more importantly, the students who are receiving that instruction.

The systems-based model

Figure 1 contains a systems-based model of technology integration that uses mentoring as the main approach to professional development. Systems promote successful learning in

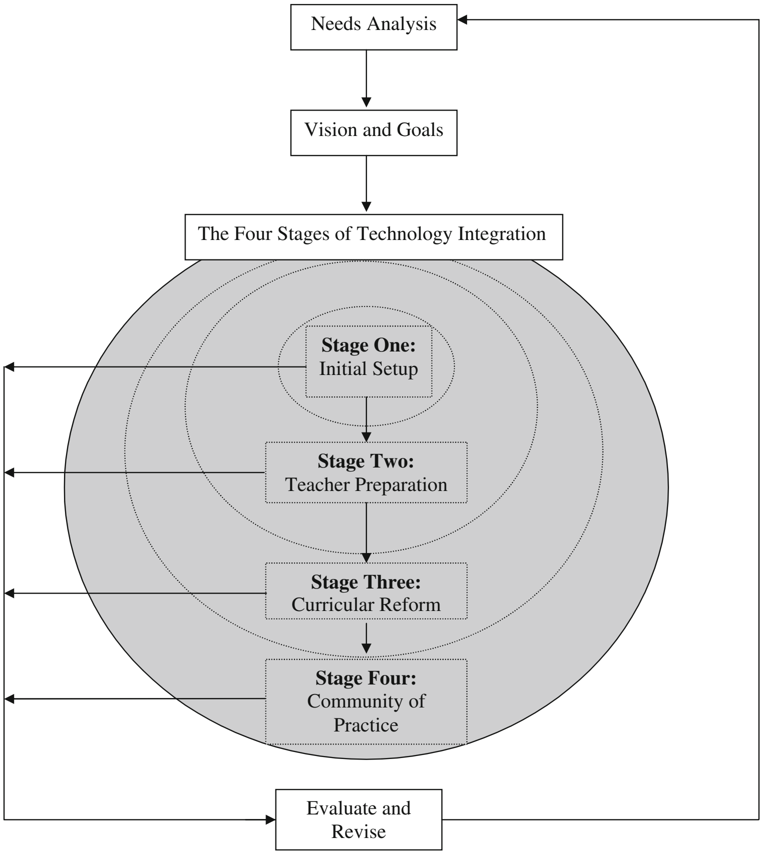

Fig. 1 Systems-based mentoring model containing the four stages of technology integration

several ways: by considering the needs of all stakeholders, by organizing and focusing interventions on a set of specific goals, and by repeatedly assessing progress toward those goals (Dick et al. 2001; Morrison et al. 2004; Reiser and Dick 1996). Using a system to facilitate the process of technology integration and promote student-centered approaches to using technology for learning is important because it helps the mentor accommodate the complex evolutionary nature of the process and individualize each teacher's process of learning to integrate technology.

There are four main stages of technology integration in the model: initial setup (Stage One), teacher preparation (Stage two), curricular focus (Stage three), and community of practice (Stage four). These appear in overlapping circles in the model. The mentor begins the model with an assessment of needs, which leads to the creation of both a vision of technology integration and short- and long-term goals for achieving that vision. Next, the first of the four stages begins. After Stage one is complete, a formative evaluation is conducted and the system begins again. The arrows in the model indicate the recursive nature of the system, where the results of the evaluation lead to a smaller assessment of needs and a subsequent revision of the goals on an as-needed basis. After revising the goals, the next stage in the model, Stage two, begins. This continues until Stage four is reached. The main steps of the model (needs assessment, vision and goals, the four stages to technology integration, and evaluation and revision) are described in detail below.

Needs assessment

The entire system begins with an analysis of the teachers' needs because professional development that directly addresses the needs of the teachers is more appealing to them (Cole et al. 2002; Ertmer 1999; Hinson et al. 2005). The mentor can perform this analysis by assessing teachers' skill levels with technology, their pedagogical approaches to using technology, and their beliefs regarding the use of technology for learning. The mentor should also assess teachers' access to working technology, the presence of a culture that supports the use of technology for learning, and the current goals and vision for technology use. Conducting surveys, observations, and interviews will provide the mentor with self-reported data validated by independent observation regarding each teacher's experience with technology integration and educational technology practices (Kopcha and Sullivan 2007).

Vision and goals

The needs identified in the initial analysis help determine the overall vision for technology use, as well as appropriate short- and long-term goals for the teachers and the technology. A clear vision regarding the use of technology is important to teachers. Staples et al. (2005) presented three case studies of urban elementary schools integrating technology into their curriculum and recommended that schools adopt a strong vision for using technology because the vision serves as a guide for teachers as they encounter problems with technology. Hayes (2007) interviewed teachers from six schools in Australia and noted that teachers from schools with a strong curricular vision integrated technology more frequently.

The short- and long-term goals created during this part of the system inform teachers about what they are expected to do and how they are expected to do it. Because teachers adopt technology at very different rates and for very different reasons, some goals will be tailored to the specific needs of each teacher while others will be designed for small groups that share a commonality such as grade level or subject-matter taught. Creating these goals with input from teachers and administrators will help establish stronger teacher buy-in, meaning they will be more likely to support the technology integration efforts if they helped create the goals for using it. Zhao et al. (2002) noted this after evaluating the technology practices of 10 K-12 teachers, suggesting that technology be used in ways that align with the goals of the teachers and the school.

The four stages of technology integration

Figure 1 contains a set of four overlapping circles that represent the four main stages of technology integration in the model: initial setup (Stage one), teacher preparation (Stage two), curricular reform (Stage three), and community of practice (Stage four). Each of the four stages of technology integration deals with the same four areas related to technology integration: mechanics, systems, culture, and curriculum. Mechanics focuses on the proper setup of technology at the school and on troubleshooting common issues with technology. Systems focuses on setting up methods of using technology that reduce the management issues teachers experience when integrating technology into their lessons. Culture focuses on the attitudes and beliefs of the teachers and improving them to minimize the impact of negative attitudes or resistance to integrating technology at the school. Curriculum focuses on integrating technology into class lessons and using student-centered approaches to teaching with technology. Figure 2 contains a Stage progression matrix that outlines the focus and major activities of the mentor during each of the four stages of technology integration and within each of the four areas.

The overlapping circles that contain the four stages of technology integration indicate that the concerns related to each lower stage continue to be a concern for each higher stage, but to a lesser and lesser degree. The circles also indicate that the stages each build upon each other. Mechanics and systems are of major concern in Stage one, but of less concern in Stage three or four when the model is underway. Likewise, the mentor is likely to find it more difficult to deal with the issues of culture and curriculum in Stage three if issues of mechanics and systems go unresolved in Stage one. A description of each stage of technology integration can be found below.

Stage one: initial setup

Researchers have noted that teachers often abandon technology integration efforts if the technology is not working properly or if the technology is outdated (Bauer and Kenton 2005; Ertmer 1999; Lim and Khine 2006; Norris et al. 2003). Therefore it is important that the main goal for the mentor during Stage one be to work with teachers to minimize the barriers that interfere with their use of technology. Teachers who learn to troubleshoot technology problems with the aid of a mentor have been found to successfully and independently troubleshoot future technology problems (Franklin et al. 2001; Smith and Smith 2004).

Mechanics Access to consistently working and up-to-date technology is important to teachers and contributes to the successful integration of technology (Bullock 2004; Easley

	Mechanics	Systems	Culture	Curriculum
Stage One Initial Setup	Train teachers to troubleshoot problems and resolve existing issues with technology (Bauer & Kenton, 2005; Franklin et al., 2001; Lai et al., 2002; Smith & Smith, 2004).	Develop systems and a physical environment that reduces the time teachers need to manage technology (Easley & Hoffman, 2000; Ertmer, 1999; Hew & Brush, 2007).	Provide reliable access to technology (Clark, 2006; Vanatta & Fordham, 2004). Create a technology committee (Hinson et al., 2005; Whitehead et al., 2003).	Model simple yet effective ways of teaching with technology (Ertmer, 2005; Zhao & Frank, 2003; Zhao et al., 2006).
	Main Focus of the Mentor			
Stage Two Teacher Preparation	Less time is spent on troubleshooting and getting technology to work properly.	Establish a system for training and following the progress of each teacher. Focus on teachers who lack basic skills (Rakes et al., 2006).	Provide support in the form of modeling practices with technology (Ertmer, 2005; Hughes, 2005; Matzen & Edmunds, 2007) and follow-up visits (Atkins & Vasu, 2000; Bradshaw, 2002; Feist, 2003).	Provide leadership needed to integrate technology into curriculum (Lai et al., 2002; Marcovitz, 2000). Present integration as easy and useful, even in student-centered ways (Hu et al., 2007; Rochelle et al., 2001).
		Main Focus of the Mentor		
Stage Three Curricular Focus	Time will be split (not always equally) between troubleshooting old technology and setting up new technology.	Evaluate, refine, and/or remove systems from earlier stages. Create new systems as technology demands increase.	Create small communities of practice (Clark, 2006; Hughes & Ooms, 2004). Use monthly newsletters and digital libraries to share ideas about technology integration.	Teachers design activities that are student-centered in nature (Hughes, 2004; Koehler & Mishra, 2005). Enlist more administrator support (Cole et al., 2002).
			Main Focus of the Mentor	
Stage Four Community of Practice	Continue to troubleshoot and update the mechanics that are set in place. Train teacher leaders to troubleshoot problems.	Create a system to sustain community of practice such as reducing the workload of teachers (Snoeyink & Ertmer, 2001-2002).	Form teacher technology leaders who will become the technology mentors for their peers (Glazer et al., 2005).	Continue past strategies to deal with disruptions that the changes in mentorship may cause (Zhao & Frank, 2003).
			Main Focus of the Mentor	

Fig. 2 Stage progression matrix

and Hoffman 2000; Hayes 2007; Lim and Khine 2006; Norris et al. 2003). Norris et al. (2003) surveyed approximately 4,000 K-12 teachers and found that lack of access to working or current technology was their largest barrier to technology integration. For this reason, the mentor begins the technology integration process by helping teachers resolve the immediate problems they have regarding access to technology. Such tasks would include troubleshooting connectivity issues, repairing non-functioning technology, updating software and hardware, and utilizing existing technical support to assist in repairing or replacing non-functioning technology. This complies with Earle's (2002) point that, while barriers to technology integration may never be eliminated, successful technology integration empowers teachers to successfully manage the barriers they face with the technology that is available to them.

Systems Teachers have reported that time issues associated with management, such as getting students to start computers or navigate to certain software, also interfere with their ability to teach with technology (Bauer and Kenton 2005; Hew and Brush 2007; Lim and Khine 2006). Creating a supportive physical environment can help reduce the time issues associated with this barrier and help teachers integrate technology (Becker and Ravitz 2001; Ertmer 1999). Both Easley and Hoffman (2000) and Becker and Ravitz (2001) similarly noted that efforts to integrate technology into the classroom were more successful when they considered the placement of hardware, created systems for signing out technology, and improved the arrangement of rooms containing technology. Other strategies include placing portable technology in a central location, creating student-friendly start-up and shutdown procedures, making software applications easy to access on each computer, and creating a school-wide set of rules for using technology.

Culture A teacher's decision to use technology is based in part on how they see their peers react to and accept new technology (Ertmer 2005; Hu et al. 2007; Zhao and Frank 2003) and their own beliefs about how technology improves student learning (Lim and Khine 2006; Norris et al. 2003). A culture that supports and promotes technology adoption and the adoption of new teaching practices is one that encourages risk-taking, immerses the teacher in technology use, and provides ongoing support (Clark 2006; Ertmer 2005; Finley and Hartman, 2004; Vanatta and Fordham 2004).

At this early stage of the model, the mentor begins to create a culture that embraces technology by resolving issues related to access and time. Clark (2006) conducted a Delphi study with 58 high-school teachers who reported that having a culture of support and assistance was more important to their technology integration efforts than improving the curriculum or receiving professional development. The mentor can create this culture by establishing a team of stakeholders, including teachers, administrators, parents, assistants, and technicians, who are devoted to the technology integration process. Establishing this team is important because it facilitates teacher buy-in and prevents the technology integration process from becoming the agenda of one or a few people (Hayes 2007; Hinson et al. 2005). This team would be responsible for making decisions about curricular policies, contributing to school-wide technology goals, and disseminating information regarding the curricular and policy changes that often come with the integration of technology.

Curriculum At this point in the process of technology-integration, any efforts to teach the pedagogy related to technology integration should consist of methods that are easy to incorporate and that take little to no time to learn or implement (Ertmer 2005; Zhao and Frank 2003; Zhao et al. 2006). This may include the use of teacher-centered practices such as drill-and-practice activities, computer-based instruction, or self-guided tutorials. While these approaches may not be the optimal approaches recommended in the literature, focusing initially on these approaches is likely to lead to more complex uses in the future (Ertmer 2005; Zhao and Frank 2003; Snoeyink and Ertmer 2001–2002) and promote long-term changes in teacher's practices with technology (Matzen and Edmunds 2007).

Stage two: teacher preparation

The main goal for the mentor during Stage two is to begin preparing teachers to use technology in student-centered ways.

Mechanics While mechanics and systems are of major concern in Stage one, they are of less concern in Stage two. While the mentor can still expect to spend time dealing with issues related to mechanics in this stage, it should be much less than in the previous stage.

Systems During this stage of technology integration, the mentor uses the data collected during the needs assessment to create a system for addressing each teacher's individual needs regarding technology skills and pedagogical approaches to teaching with technology. The mentor should focus on teachers who are lacking basic skills with technology, because having basic technology skills is a critical component to more complex uses of technology for teaching (Hew and Brush 2007; Ertmer 2001; Rakes et al. 2006; Zhao et al. 2002).

The mentor may also need to help teachers contend with the many forms of technology available to them. As teachers begin to gain proficiency with one piece of technology, the introduction of new technology often causes them to lose confidence in their abilities and can negatively affect their beliefs about using technology for learning (Atkins and Vasu 2000; Ertmer 1999; Zhao and Frank 2003). Tailoring the process of technology adoption to the individual needs of each teacher is most likely to help teachers overcome those negative effects and foster long-term, meaningful uses of technology to enhance learning (Ertmer 2005; Hew and Brush 2007; Kanaya et al. 2005).

Mentors can create this system by establishing formal group meetings with teachers such as weekly team meetings (Gallagher 2000), assisting teachers during technology-enhanced lessons (Smith and Smith 2004), and by conducting informal meetings such as walking room to room on a daily basis (Marcovitz 2000). The mentor can use those meetings to train teachers, demonstrate ways to integrate technology that align with the pedagogical beliefs and practices of the teachers, and discuss new ways to integrate technology. Marcovitz's (2000) observations of a computer coordinator revealed that regular meetings with teachers became a forum for discussing pedagogy and curricular changes and for making plans for using technology in the future. The regular attention given to teachers in this system ensures that teachers have the support needed to continue using technology even as they fluctuate in their acceptance and use of technology for learning.

The mentor should also begin working with teachers who are already experts at using technology because these teachers are useful as advocates of technology across the campus, can share materials and experiences regarding technology use, and can be used in the future as mentors for teachers with less experience integrating technology into the curriculum. Mentors will want to work closely with these teachers during this stage because these teachers are most likely to readily adopt and promote student-centered approaches to teaching with technology (Whitehead et al. 2003).

Culture Cultivating a culture that embraces student-centered approaches to teaching with technology begins by introducing teachers to practices with technology that are pedagogically aligned with each teacher's current approach to teaching (Barron et al. 2005; Ertmer 2005; Zhao et al. 2006; Zhao and Frank 2003). Hu et al. (2007) noted that teachers are more likely to use technology on a regular basis if they perceive it as something that is easy to do because this improves their belief that the technology is useful. To develop a culture that complements the technology integration efforts, the mentor may need to challenge negative beliefs and present technology as being useful for learning.

Because teachers are likely to teach with technology in ways that they have witnessed or been taught (Ertmer 2005; Hew and Brush 2007; Hughes 2005; Matzen and Edmunds 2007), the mentor should begin modeling the student-centered uses of technology that teachers are expected to adopt. Modeling has been advocated as a way to change teachers' negative beliefs about technology, expand their current perception of technology integration, and create a culture that embraces technology (Ertmer 1999, 2005; Glazer et al. 2005; Vanatta and Fordham 2004). Waight and Abd-El-Khalick (2007) found that a teacher interested in using inquiry-based approaches to learning science was unable to do so in an effective manner because she had no mental model for teaching in such a way. Modeling technology use is important because teachers are more likely to adopt new approaches to teaching with technology if they have witnessed them in the past (Matzen and Edmunds 2007).

The mentor should also provide teachers with follow-up support to any training they receive. Researchers have suggested that teachers who receive training with future follow-up sessions are more likely to integrate technology in ways that support learning (Atkins and Vasu 2000; Bradshaw 2002; Feist 2003; Joyce and Showers 1995). These follow-up sessions can be used to encourage teachers to continue using technology and the skills needed to integrate technology successfully (Bradshaw 2002), to discuss student-centered teaching approaches (Ertmer 2005), and to provide emotional support as teachers struggle with teaching in new ways (Smith and Smith 2004). Although establishing a culture that accepts and embraces teaching with technology using student-centered approaches clearly takes time, it is critical to efforts aimed at getting teachers to continue integrating technology beyond their initial training and in ways that support student learning.

Curriculum The mentor's focus on the curriculum is limited at this point by efforts to create a perception that using technology is easy to do and useful to teachers. Efforts to integrate technology into the curriculum are likely to consist of practices that align with teacher beliefs and skill levels, such as using the computer to deliver instruction or having students produce documents that were previously created by hand. At the very least, this can improve the frequency of technology use and the likelihood of its adoption (Hayes 2007; Kanaya et al. 2005).

Lai et al. (2002) and Marcovitz (2000) noted that a mentor could provide direction, focus, and purpose for teachers as they integrate technology into their lessons. Since teachers' beliefs about technology impact their future use of technology (Donovan et al. 2007; Vanatta and Fordham 2004), the mentor can begin to provide the leadership that teachers need to succeed in their efforts to integrate technology into the curriculum. This means presenting the integration of technology into the curriculum as something that is useful and easy to do, even in student-centered ways. Hu et al. (2007) and Rochelle et al. (2001) recommended this as a way to help teachers adopt practices with technology that are more student-centered in nature.

Stage three: curricular focus

The main goal for the mentor during Stage three is to increase teachers' experiences with the pedagogy needed to employ technology in student-centered ways.

Mechanics At this stage of the model, problems with technology should be minimal, consisting of minor troubleshooting and upkeep. However, it is likely that new technologies will have been introduced or updates to existing technology will have occurred.

These may create problems that negatively affect teachers' use of technology (Zhao et al. 2006; Zhao and Frank 2003; Brzycki and Dudt 2005). The mentor plays a crucial role in ensuring that new or updated technologies run properly and are available to teachers across the campus.

Systems The mentor will spend time evaluating and refining existing systems and designing new systems that are needed as technology is more widely used, but the amount of time needed for this area will be less than in the previous two stages. The mentor should continue to monitor the progress of each teacher and plan appropriate training and follow-up training for each teacher as needed.

Culture At this point in the model, the mentor can begin to cultivate small communities of practice that focus on adopting student-centered practices with technology. Teachers have reported that they desire opportunities to share ideas and experiences regarding technology integration (Clark 2006) and these opportunities have been found to lead to greater and more sophisticated technology use (Cole et al. 2002; Finley and Hartman 2004; Hughes and Ooms 2004; Vanatta and Fordham 2004). The mentor can help establish opportunities for teachers to collaborate by creating consistent meeting times and by encouraging them to share lessons and technology-integration ideas by grade level and by content area. If finding time to meet in person is problematic, the mentor can promote collaboration by producing a monthly newsletter highlighting the different uses of technology across grade levels and by creating a digital library in a shared drive or an offsite server that allows teachers to contribute and share electronic materials from their desktops.

Curriculum During this stage, the mentor deliberately connects subject-specific content with student-centered approaches to learning. Combining technology integration efforts with a change in curricular focus is more likely to lead to long-lasting integration practices among teachers (Rochelle et al. 2001; Zhao et al. 2006; Whitehead et al. 2003). The mentor can begin to change the curricular focus by helping teachers design activities that align with the curriculum and incorporate student-centered approaches to using technology. Hughes (2004) and Koehler et al. (2007) both suggested that having teachers design lessons that incorporate technology and focus on supporting learning would result in greater and more complex uses of technology in the future. It is important for teachers to participate in the design of these lessons because attempts to fit technology into the curriculum where teachers feel it does not enhance learning or make an obvious fit can ultimately lead to failure (Hinson et al. 2006).

The mentor may need to motivate teachers to adopt student-centered approaches to teaching and to take the time needed to create technology-enhanced lessons. Strategies for motivating teachers to do so include creating an environment of risk-taking (Matzen and Edmunds 2007), offering funding as incentive to create new units (Cole et al. 2002; Swan and Dixon 2006), and enlisting the support of the principal (Cole et al. 2002; Hayes 2007). Implementing these strategies establishes a culture that values the teacher and the use of technology as a tool for enhancing learning.

Stage four: community of practice

The main goal for the mentor in this stage is to move the existing system, which is expert-led, to one that employs faculty and other resources from the school site. During this stage the mentor trains teachers and faculty to become technology leaders for the school. Once teacher leaders lead the system, the mentor's role may be altered to part-time status as a support for the teachers and teacher leaders, or eliminated outright.

Mechanics The mentor now spends time training the technology leaders on troubleshooting the problems that occur with the existing technology and making them aware of any outstanding issues that exist regarding the technology.

Systems The mentor should help develop a system for sustaining the support that is in place for using technology. This includes establishing a system of financial or other incentives for the teacher leaders, such as a reduction of workload (Brzycki and Dudt 2005; Snoeyink and Ertmer 2001–2002; Swan and Dixon 2006).

Culture The mentor will spend time moving the current expert-led culture to one that is teacher-led and even more collaborative in nature. The benefits of creating a teacher-led community of practice include motivating teachers to explore new uses for technology and to help them overcome the barriers they face when doing so. Hughes and Ooms (2004) found that a technology support group provided teachers in the group with support that was relevant to each teacher's situation as they created and implemented technology-enhanced lessons. Glazer et al. (2005) suggested that placing teachers in collaborative groups would improve teacher motivation and empower them to learn about, use, and design lessons for technology. The collaborative approach promotes sustainability because each generation of technology-using teachers serves as mentors for other teachers and thus creates new mentors for the future.

Students of the teachers may also provide mentoring for teachers, as they often possess the skills needed to use and troubleshoot technology (Clark 2006; Ertmer 1999). Graduate students or preservice teachers from local universities can also be called upon provide support to the teachers learning to use technology at little to no extra cost to the school (Ertmer 1999; Franklin et al. 2001; Smith and Smith 2004).

Curriculum Because teachers are now the technology leaders at the school and the mentors for other teachers, they may be in a precarious position of pushing their peers to teach in different ways. This may fail or, worse, backfire, pushing teachers to reject technology and resent their peers. The strategies employed during the earlier stages of the model aim to reduce the risk of such an occurrence. The mentor should assist the technology leaders as they continue promoting the culture-related strategies employed in previous stages.

Evaluation and revision

After each of the four stages of technology integration, the mentor should measure the progress made toward the goals and vision created earlier in the model. Formative evaluations during technology integration initiatives are important because they inform stakeholders about the progress that is being made and the mentor of any issues that arise during the initiative (Whitehead et al. 2003). This is important to the mentor's efforts to align the technology-integration process to the needs of each teacher and for deciding if the technology integration effort is ready to move into the next stage.

Discussion

It is important to note that, while the model is presented in a linear manner, the process outlined in this article is not intended to be a rigid one. This is similar to many instructional design models (see Dick et al. 2001; Morrison et al. 2004; Reiser and Dick 1996), which present several separate steps all aimed at one goal: designing effective instruction. In the case of this system, the set of small steps are the stages to technology integration, which all work toward the goal of supporting teachers as they learn to integrate technology in a way that supports student learning. While each stage of technology integration in the model must work in conjunction with the other stages, the attention each receives may vary from setting to setting, and even from situation to situation within a given setting. Also similar to many models of instructional design, the process for completing the steps is determined by the unique constraints identified in the needs assessment and by the experience level of the person using the system, where more experienced users are likely to tailor or modify the model to suit their needs.

Using a systems-based approach to technology integration creates a teacher-centered process for integrating technology. The mentor provides just-in-time support, modeling, and apprenticeship that is situated in the context of the teachers' classrooms. This is important because it could translate into more complex and substantial uses of technology for learning. Researchers have suggested that these approaches to learning lead to higher levels of motivation, deeper levels of learning, and skills that are transferable to new and unknown situations (Brown et al. 1989; Duffy and Jonassen 1992; Glazer et al. 2005).

The model is recursive, making it robust to the changes teachers experience with regard to the multiple barriers they face as they learn to integrate technology. The repeated evaluations of progress throughout the model ensures the alignment of the technology integration efforts with the constantly changing needs of the teachers, including needs that have yet to come. For example, Bauer and Kenton (2005) unexpectedly found that a lack of technology skills among the teachers' students held teachers back from using technology to enhance learning. It is not difficult to envision a number of other common external issues that could interfere with technology integration efforts, such as changes in school policy, the introduction of new technology, new leadership efforts, and changes in staffing. A mentor using this system can help teachers quickly learn to manage and reduce the impact of barriers such as these, a skill that is not likely to be addressed in a stand-alone skills-based workshop.

The system is flexible enough to support many different types of technology initiatives, including one-to-one laptop initiatives, computers on wheels, or handheld technology, and can be applied in more common technology settings such as centralized computer labs or sets of computers within the classroom. For example, Donovan et al. (2007) examined the integration process of 17 seventh-grade teachers adopting a one-to-one laptop initiative. They suggested that future integration efforts focus on differentiating training based on the needs and concerns of each teacher, making professional development relevant and meaningful, and focusing on the process of integration as an ongoing effort to address teachers' concerns. The system presented in this article incorporates those suggestions by focusing on meeting teacher's needs, managing barriers to technology use, and aligning efforts at integrating technology with the unique needs of the setting in which it is applied. Because of this, the model is likely to be applicable to both present and future initiatives that integrate technology into the practices of teachers.

Although the model is presented with research that is primarily conducted in K-12 settings, has the potential for application in higher education settings because barriers to technology integration are similar in both settings. Adamy and Heinecke (2005) found that higher education faculty members were more likely to use technology when it was consistently available and working. Finley and Hartman (2004) found that five faculty members who integrated technology into their teaching reported needing more time to do so, wanting a culture that supported them, and requesting professional development that was relevant to their needs. Feist (2003) successfully used mentoring to help 10 higher education faculty members overcome barriers such as access, knowledge, and professional development while learning to design online instruction. Educators who are trying to integrate technology into their teaching, either in K-12 or higher education settings, universally desire the just-in-time support and individual attention provided by this model.

It may seem as though some teachers under this model will never integrate technology on a regular basis or learn to do so in more student-centered ways because the model allows each individual teacher to progress at a rate that suits his or her individual needs. However, Matzen and Edmunds (2007) found that teachers who are taught to use technology in student-centered ways would also teach with technology in the same way, even if their core beliefs were not aligned with such practices. This supports Earle (2002) who suggested that teachers would use technology to enhance student learning when integration efforts focused more on learning to teach with technology and trying new approaches to teaching, rather than on technology skills alone. While this model may not guarantee that teachers begin to use technology in student-centered ways, it does help increase the chances of doing so. Unlike other models of technology integration that focus solely on *how* to teach with technology (see Friedrichsen et al. 2001; Hinson et al. 2006), it focuses first on empowering teachers by helping them manage the many barriers they face before learning to teach in new ways with technology.

Conclusion

Moving teachers toward using technology in student-centered ways is a multi-faceted effort that has a better chance of success when implemented over longer periods of time and with appropriate support, such as mentoring. However, mentoring models of technology integration have been criticized because they place too high a demand on school resources such as time, money, and teacher support (Chuang et al. 2003; Gallagher 2000). This model addresses these criticisms by reducing the demands commonly associated with the use of an outside expert such as a mentor and promoting long-term integration efforts. Both are achieved through the development of a community of practice around technology.

Future research possibilities on a model such as this include developmental studies on the implementation of the model in real settings. Neiderhauser and Lindstrom (2006) noted that technology is at a point of saturation in schools that allows researchers to focus on how, rather than if, teachers are using technology. More research is needed on the effectiveness of the student-centered practices teachers employ when using technology and the impact of mentoring on these practices. Other research possibilities include examining the impact of this model on the teaching practices of teachers over a multiple years and, in particular, the development of a community of practice supporting technology integration.

The model presented in this article is an attempt to bring together prior research on technology integration in a cohesive system that accommodates the needs of teachers during current and future initiatives with educational technology. While implementing this model will take time, patience, and a commitment to supporting teachers as they learn to integrate technology, doing so is an essential step toward substantiating the use of technology to enhance learning and achieving the vision of technology integration presented in the literature.

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