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Bridging Teacher Networks for ICT Adoption

"I believe that the motion picture is destined to revolutionize our educational system and that in a few years it will supplant largely, if not entirely, the use of textbooks" (Thomas Edison).

Abstract

Over the past decade, education reform has spent a great deal of effort to create and support Information Communication and Technology (ICT) projects in order to increase student achievement. For the most part, these projects have been created in isolation from the social context inside of which teachers work. I argue that focusing on technical or professional development "solutions" as the mechanism for leveraging student achievement or education reform deprives us of understanding the socio-technical interaction between teachers and an ICT intervention that may increase the success of that intervention. In this paper, I seek to help education technologists, policymakers and administrators understand the nature of K-12 education ICT interventions -- specifically their relationship to teacher networks. Furthermore, I suggest a framework for future research in this interaction between ICTs and teachers in K-12 schools.

Introduction

The past two decades have witnessed the widespread deployment of ICTs in American K-12 schools. Along with deployment came expectations that new education technology would leverage student achievement and reform American education. However, resulting teacher use of technology in classrooms disappointed many policymakers and system designers. The release of A Nation At Risk began what would be over twenty years of heavy investment and research into education technology. With the hope of raising a generation of science and technology savvy workers who could compete in the information age, billions of dollars have been invested into hardware deployment and software development. Despite critiques of the policy regarding low, meaningful teacher use of classroom ICT systems, the 2004 release of the National Education Technology Plan furthered the national commitment to education and ICT integration.

Early research has attempted to study the effect of such widespread deployment of ICTs. Some studies hoped to draw relationships between system design and student learning. They asked questions like: “How many students have access to ICTs? How many teachers are using computers in their classroom?” Later research began to ask more difficult questions about ICT use in schools like: “What is the relationship between school leadership and ICT use? To what extent does professional development influence ICT adoption in classrooms? What factors lead to teacher refusal to adopt ICTs in classrooms?”

This paper aims to engage in a comprehensive discussion of the role of teachers during implementation of an education ICT. I propose further research on the social context of teachers during an ICT intervention, specifically, the extent to which teacher networks of ICT practitioners and non-practitioners are closed, preventing extensive adoption and the spread of innovation. Flows that would normally create a healthy environment of information exchange are hampered, and perhaps inhibit ICT innovation. Furthermore, I suggest a few guidelines to develop processes that addresses adoption of

ICTs in the education community.

Overview

In 1983, the federal report A Nation At Risk recommended that “computer science” be included in high school graduation requirements (McMillan). Since then, over \$40 billion dollars has been invested in infrastructural, technical and professional development (Dickard). In 2004, the U.S. Department of Education stayed the course, continuing previous beliefs about the necessity for education ICT, and released its National Education Technology Plan. The document sets the agenda for education technology to complement schools with online testing, real-time feedback, data use for tracking systems, needs assessment, demographic analysis and instructional design (United States). In 2008, \$46.5 Billion USD was spent on ICT for education (Nagel). Faced with the task of enhancing and improving American K-12 education, policymakers choose to invest in educational technologies because technology has been perceived as an agent of change, as a tool to address challenges in teaching and learning, and as a central force in economic competitiveness.

In the early eighties, some industry leaders and policymakers began to worry that the United States was losing its edge in science and technology. The threat of a creeping science and technology crisis motivated a large amount of support for increasing United States investment in research and education. A growing number of nations began competing with the U.S. in science and high-technology markets that were historically American dominated. After the end of the Cold War, a wave of reports suggesting that globalization and the growing strength of other nations in science and technology could threaten the U.S. position as a global leader (RAND). Since this time, education practitioners and policymakers have made supporting and advancing high-quality use of educational technology in K-12 settings a prominent concern.

ICTs have also been used in a variety of efforts aimed at fostering teacher learning and collaboration, student learning and collaboration (Zhao and Frank). States have begun to adapt new technologies to student testing and assessment, tracking and analysis (Tucker). Students are increasingly seeing ICTs as closely tied to the activities and tasks that make up their lives, and therefore rely on them to help them do their school work (Levin and Arafeh).

Many policy reports emphasized the ability of technology to catalyze education reform in American schools. ICTs were seen as a means to move away from traditional lecture-driven instruction toward a more constructionist, collaborative oriented learning environment. These reports, believing in the ability of technology to help in day-to-day classroom instruction, were founded on assumptions that it is possible to create the right set of technological tools for a classroom or subject and match them to a specific scenario (McMillan). These policies called for research to be done in order to identify the right set of conditions that must exist before assimilating technology into the classroom. Other reports highlighted the ability of technology to address challenges in teaching and learning. Distance learning, delivering instruction to populations where high-quality educational access is limited, seemed like an area that benefited greatly from ICTs that could “extend teaching and the learning process” (United States, “Power On!”). The quality of instruction could increase if teachers could understand and use assessment data with greater ease. The amount of students reached could increase by using individualized programs or software. Overall, policymakers have attempted to create an environment in the United States where students are instructed about technology, learning the specific technology skills or about the software or hardware; from technology, where students use a computer to go through tutorials; and with technology, where teachers use technology in innovative ways to engage students.

Receiving impetus from policymakers, ICT industry leaders have reinforced the beliefs and assumptions of these policy reports. Microsoft chairman Bill Gates testified before the Senate that he believed the economic future of the U.S. was in danger unless American students were equipped with

the skills needed to be successful in a modern economy. In his view, progress can be made through public-private partnerships like Microsoft's Partners in Learning Program (Gates testimony). It is important for industry leaders to have an educated work-force. In their view, it is equally important for workers to be technologically skilled, especially in an age of "information capitalism", in order to increase their economic opportunity (Castells). Both policymakers and industry leaders have continued policy that reflects their belief in the need to American citizens to have a technological edge in order to compete in a globalized and highly skilled labor market.

"The transformation of the world economy increasingly demands a more highly educated workforce with postsecondary skills and credentials. Ninety percent of the fastest-growing jobs in the new information and service economy will require some postsecondary education. Job categories that require only on-the-job training are expected to see the greatest decline. In high-demand fields, the value of postsecondary credentials and skills is likely to rise. The Department of Labor projects, for instance, that by 2014 there will be close to four million new job openings combined in health care, education, and computer and mathematical sciences"(United States).

System designers have viewed the field of education as rife with technological problems that are in need to be solved. Since the beginning of the 20th century, technologists have been hopeful that ICTs could transform education. Early on, innovators like Thomas Edison believed that technology could ultimately replace traditional methods and tools for education. They stressed the ability of ICTs to bring the world to the classroom and aid in instruction. Designers have seen ICTs as a disruptive innovation that could supplement and transform traditional classroom content. Many early classroom ICTs were designed to drill and tutor students, track their progress and deliver results quickly. Later on, some went as far as to claim that computers can help children achieve meta-cognition quicker, understanding how the mind works when solving problems. M.I.T. mathematician Seymour Papert called the computer the ultimate learning material because of its ability to be anything to anyone. He, along with others with a constructionist learning background, advocated computers with an exploratory learning approach in order to bring about not only improved technical fluency but also greater

cognitive ability.

Researchers sought to understand the effects of the rapid and widespread ICT deployment in American schools. By 1984, about 56,000 of 82,000 schools had at least one computer for every 92 students (Cuban). In 2006, there were about 14.2 million computers available for student use, translating to about four students for every computer (The 2009 Statistical Abstract). Some believed that technology did have the potential to drastically improve our current assessment systems and practices, pointing to examples where ICT use in schools lead to significant improvements in teaching and learning (Lieberman). Other researchers also supported educational ICT interventions, finding in their research the potential to dramatically improve assessment systems, creating drastic improvements in teaching and learning (Tucker).

There have been, however, a large number of researchers who have rebutted the extent to which many claim that technology can reform or change education. These critics ask why technological innovations that have seemingly revolutionized business and social practice have not become widespread in K-12 schools. They assert that technological innovations favored by the research community, intended to support inquiry, collaboration, or re-configured relationships among students and teachers continue to be used by only a tiny percentage of America's teachers (Cuban). Some argue that it is because previous research does not address issues of usability, scalability and sustainability (Fishman et al.).

Others have argued that attempts to reform education through ICTs largely fail because the emphasis is placed on easily quantifiable factors such as money spent, structural development and skills training. Such factors ignore harder to define processes associated with human behavior change. They argue that if ICT is a disruptive and innovative technology, reforms need to pay special attention to the behavior of users as they interact with the technology (Szabo).

Paul DiMaggio et al.'s study of inequality in access and differentiated use of ICTs sparked a

heated discussion of the possibility of a “digital divide” between those who have access to the Internet and those who do not, as well as inequality among the people based on the extent to which they are able to use the Internet and if that affects their life chances (Norris, Warschauer). Despite the various conclusions about the cause, most researchers agree that it is not enough to install computers and wire classrooms for internet use, but the focus of research needs to expand to how schools use technology.

Defining a successful ITC intervention in education has been difficult in the past. National standards for school technology use have been suggested in order to set the expectation for teachers to use technology to “design, implement, and assess learning experiences to engage students and improve learning; enrich professional practice; and provide positive models for students, colleagues, and the community” (NETS). Previously, we have measured the success of such projects using quantitative studies that measured student or teacher use of the ICTs. Such studies asked questions like “How many students have access to computers and the Internet in a school?”, “How many teachers have computers in their classroom?”, “How many teachers use ICTs in their day-to-day teaching or planning?”, “Is there professional development available in order to train teachers to use ICTs ‘properly’?”. Currently, researchers are beginning to ask more difficult questions about ICT use in schools: “What is the relationship between school leadership and ICT use?”, “To what extent does professional development play in ICT adoption in schools?”, “How can widespread ICT adoption lead to inequality among students or schools?”, “What factors lead to teacher refusal to adopt ICTs in their classrooms?”, “What are the obstacles to ICT integration in classrooms?”.

Currently, the focus of interventions is based on the idea that the most important factor favoring school reform is the impact of the information age on American culture (Mehlinger). High levels of technology use in schools is a current policy goal. The worthiness of this goal will not be discussed in this paper. However, in the future, it is my hope to question the way in which we evaluate the success of an ICT intervention, although this is also not the goal of this paper. For example, what are other

ways to measure the success of an ICT intervention besides high levels of technology use? It should also be mentioned that achievement in schools in high income areas and low income areas is outside the scope of this paper. The differences between technology use in high-income schools and low-income schools is another area in which more research is needed.

Problems with Past Approaches

“The problem is not necessarily lack of funds, but lack of adequate training and lack of understanding of how computers can be used to enrich the learning experience” (U.S. DOE, 2004, p. 22)

As we can see, much effort in the past few decades has been given to answer the question of how can technology be used to support education reform in American K-12 schools. This has been such a difficult question to answer because during planning and deployment of the ICTs in schools, the goal of empirical work was not to evaluate the overall effectiveness of technology in education. The PCAST Panel on Education Technology report (1997) recommends:

Even if it were deemed to be desirable to gather evidence for the overall effectiveness of technology in education, current educational trends would make the interpretation of such research more difficult than was the case in the early days of computer-assisted instruction. Technology has in recent years been increasingly seen not as an isolated addition to the conventional K-12 curriculum, but as one of a number of tools that might be used to support a process of comprehensive curricular (and in some cases, systemic) reform. In such an environment, attempts to isolate the effects of technology as a distinct independent variable may be both difficult and unproductive.

Policymakers were so sure that the trend toward technology use in society would make the question of technology use in school a moot point. They also point to the difficulty in attempting to evaluate the effect technology interventions might have in schools. The perceived difficulty in separating technology from teaching practice may have hampered systematic investigation into developing a coherent framework for evaluation. We should not fail, however, to attempt to understand the relationship between teachers and ICTs. To the credit of the panel, they highlight the need to view technology as one tool among many that can strengthen teaching practice.

While past research has often focused heavily on ICT innovation at the policy, administrative and structural levels, the current approach does not take the social side of ICT use into account. In this paper, I take the position that ICT use “is embedded in a complex array of factors encompassing physical, digital, human and social resources and relationships” (Warschauer). A comprehensive discussion is lacking in the current policy and scholarly discourse of the role of teacher and their social context. While a teacher may be an isolated entity within the context of the classroom, he or she is also a member of a school community. Within that community exist smaller networks of practice, pedagogy, beliefs, etc. These factors can complicate attempts to measure the effectiveness of professional development.

Policy has not provided a coherent model for quality research in ICT and education. In “A Retrospective on Twenty Years of Education Technology Policy” McMillan et al. find that of the 28 important policy statements in the past twenty years, 24 of them included specific recommendations in the following areas: access, content, professional development, funding, stakeholders, research, and regulations. Little is found beneath the surface of these recommendations; measurement of implementation can be easily achieved using a simple “has” or “does not have” model. The lack of a common discourse in ICT and education literature is apparent in the scattered nature of the recommendations. Studies ranged from the effects of ICT use in schools have found computer learning

networks have the potential to empower students when they are used appropriately (Warschauer et al.) to the probability of successful adoption of ICT is increased when school leaders (i.e. principals) model its use for staff, and thus the staff may then model the use for students (Anderson and Dexter).

In the past, the approach to research has been to assume that technology can reform education and the question is how can we get the technology into the classrooms. Then, research attempted to understand why the technology deployment didn't have the effect that we hoped. Now, a more nuanced view of ICTs in education has emerged. More recent policy and research has focused on the way ICTs can be used to make use of assessment data, to provide better professional development, and to create administrative efficiencies that can support educators in the day-to-day work with students (McMillan).

In this paper, I propose that the role of teachers during implementation be added to the education technology intervention discourse. Perhaps by further researching teacher networks, pedagogical practice and tacit teacher knowledge in relation to ICTs, patterns will emerge that could help create a framework for more effective design, deployment and implementation of education technologies in K-12 schools.

How Can We Best Research this Problem?

In order to develop a coherent framework for the problem of slow adoption of technology by teachers, we should draw from the wide range of studies many social researchers have implemented. Although they approach the problem from various angles and perhaps use different approaches, they offer a rich body of literature that may help us understand the scope, boundaries and characteristics of ICT and the social context of teachers.

To begin, I'll draw from the vast amounts of research done on social networks. The formation, structure and evolution of social networks within an education community can influence the adoption,

non-adoption or refusal of an ICT. Factors, more complex than simply the number of new teachers in a school or the size of the school, may tend to encourage or discourage ICT adoption. For example, Penuel and Riel found networks may matter when it comes to social change. They analyzed the relationships among school leadership, teacher communities and diffusion innovation in schools and found that network ties could influence teaching practice change (Penuel and Riel). Their study showed that ties to experienced teachers made the most difference in teaching practice change. New teachers that received help from other new teachers were less likely to change their teaching practice than new teachers that received help from more experienced teachers. No longer is it sufficient to wonder about the size of networks when dealing with social change, but the structure of the networks and the ties between the actors matter.

Teacher Networks and Innovation Diffusion

Understanding the role of a particular position in a social network can provide important information about the overall community. An actor near the center of a network may be in a better position to acquire new knowledge while an actor with more direct ties to the outside of a network may be better suited to spread information (Granovetter). Similarly, those members of a network with similar patterns of relationships may have similar roles in their respective networks. Everett Rogers attempted to explain how new ideas and technologies spread throughout a society “over time among the members of a social system” (Rogers). He proposes a set of stages, rates, characteristics and categories for adoption of innovation. Researchers have used the models proposed by Granovetter and Rogers in order to understand the relationship between substructures in a social network and how they are likely to behave.

Tom Valente’s work with network models showed that a person was more likely to share similar

patters of adoption of an innovation with another person with a similar social position within a different system. Individuals with different roles in a social network should have have higher or lower thresholds of adoption. For example, it may be possible to examine a social network and identify those members who are opinion leaders, early adopters, laggards and so on. Depending on the identified role based on the patterns of relationships within a network, it is possible to predict which individuals are more likely to adopt an innovation and which are more likely to resist or hold out until later (Valente).

Schlager and Fusco found that teacher networks can have a direct impact on professional development through various forms of collegial interaction in the school community. Through analysis of their work on a professional development support environment called “Tapped In”, they provide insight into the role of the teacher and communities of practice and their reciprocal relationship with teaching practice change. Drawing on existing literature, they define communities of practice as “emergent, self-reproducing, and evolving entities that are distinct from, and frequently extend beyond, formal organizational structures, with their own organizing structures, norms of behavior, communication channels, and history” (Schlager and Fusco). They believe that communities of practice are an essential part of any successful, sustained professional development program. For example, they cite the Union City, New Jersey, online project where professional development programs were designed with communities of practice in mind. By fostering awareness, practice, sharing, peer-coaching and mentoring within these smaller communities over 8 years, large-scale change was seen through the establishment of an environment of learning that supported innovation (Schlager and Fusco). The Union City example seems to show that 1) teacher networks can have an effect on school climate toward innovation and 2) inoperative communities of practice can create a culture that supports improvement over time. “Tapped In” seeks to answer the question of how to help support communities of practice by understanding the characteristics and forms they take in the education field. But it leaves other questions to be answered: What is the role of the teacher in the education community? What

affect does the attitude of the teacher have on technology adoption?

Diffusion literature suggests that the teacher's attitude toward or familiarity with a technology may play a key role in technology use. It is assumed that a teacher with a negative attitude toward technology is not likely to use it in his or her teaching. But perhaps there is more to understand here. One research project, implemented by Zhao and Frank, attempted to understand the relationship between teachers, technology and students through the metaphor of an ecosystem. Teachers are represented as a keystone species that exerts a kind of controlling influence of the entire system, computers are represented as an invading species. The foreign invader is judged by the keystone species to be helpful or harmful for its own well-being as well as the well-being of those organisms in its charge (students). Through quantitative analysis of survey results of 19 schools, they found that teachers engaged in behaviors they thought were in the best interest of their students. However, when teachers considered their own behavior, their predisposition toward the technology was more important. This suggests that teachers consider themselves simultaneously as individuals and as members of a communal social system. Zhao and Frank propose a model to understand the process of technology adoption that considers the dual attitude of teachers. Included in their model of adoption is a stage of co-evolution, where the technology and the teacher adapt to each other by changing themselves.¹

This study seems to suggest that it is possible for teachers to change their pedagogical beliefs and practices if allowed the opportunity to have a period of negotiation with the technology. A teacher can then act, both as an individual and later as a member of the school ecosystem, to better understand and evaluate the benefit of adoption of that technology. It may not be likely that social pressure can act

¹ Their findings seem to be supported by the work of Stephen Barley and Wanda Orlikowski. Both scholars investigate the ways in which existing social orders change technology upon implementation, as well as how new technology changes the social order of relationships, routines, talks, etc.

positively toward teacher adoption, since teachers think of themselves as individuals first and as members of a community second. Often, teachers feel not only as though their classrooms are invaded by an ICT, but also that the invading force is supported by other community members and administrators. Obviously, this attitude will not dispose teachers to technology adoption. Additionally, this study suggests that teachers will engage with a technology when they participate in mutualistic interactions. Teachers that strongly believe that technology can improve or is compatible with their teaching practice reported higher levels of classroom and personal use. If teachers believe that using computers is beneficial for themselves personally, they will be more likely implementors of computers in their classroom.

Teacher networks and communities play a large role in the success of any professional development program. There is a clear theoretical and empirical framework for understanding the role of a particular position in a social network as well as its relationship to the rest of that community. Further research should be done, drawing from a rich body of literature, to explore teacher networks, communities of practice and technology adoption.

Pedagogy and ICT Adoption

The question of teacher pedagogy and technology adoption is closely tied to teacher networks. Teacher's beliefs, background experiences, social influences and contextual circumstances can influence their willingness to make changes in their pedagogy (Pennell and Firestone). While teacher networks may play a role in pedagogy change, pedagogy itself may also play a role in a teacher's willingness to incorporate ICT into classroom instruction.

Pennell and Firestone suggest that variations among teachers are large enough, and important enough to design professional developments around. They found that pedagogical variation influenced

teachers' willingness to make changes in the classroom, take part in school programs and leadership roles. Programs were most effective when they took advantage of existing beliefs among teacher networks that did not conflict with program philosophies. Resistance to pedagogical change may be a major obstacle to ICT adoption in the classroom.

The Microsoft Research project "Digital StudyHall" provides an intriguing example of ICT use in order to supplement the lack of effective pedagogy through the extension of expert teaching and collaboration. Teacher training is a large problem in rural India. Very often, communities lack the resources to provide adequate training for their teachers. As a result, student achievement commonly suffers. Digital StudyHall (DSH) offers a solution to this problem by recognizing the role of the teacher in education ICT deployment. For example, a rural school is provided with a television and a video player. Expert teachers, often in urbanized areas, are videotaped to use for example lessons. The rural teacher, trained to be a facilitator of video-playback lessons, sends a request through the mail for a video lesson on a particular subject. A central hub makes a video copy of the lesson and sends it back through the mail. Upon arrival, the rural teacher plays the video for the class, pausing the video when appropriate in order to prompt class discussion about the lesson. DSH is a unique ICT education intervention in that it provides for the professional development of teachers with little additional time investment, improves the classroom teaching practice without asking teachers to reinvent their teaching practice around the technology. Minimally trained rural teachers (along with their students) benefit from the expertise of seasoned teachers and can form and adapt their own teaching practice, using the example of the recorded teacher, as they see fit. DSH draws from from the Tutored Video Instruction model, which claims results that exceed the traditional in-class performance (Cadiz et al.). Proponents of the model believe that the increased amount of discussion that occurs around facilitated video is a less inhibiting environment and fosters an enhanced learning process.

Tacit Knowledge and Adoption: Mind the Gap

In the previous section, we have discussed the role of teacher networks in technology adoption, this section will discuss knowledge transfer and issues surrounding the training of teachers for meaningful technology use in classrooms.

A 2007 survey of teachers and education institutions by the National Center for Education Statistics found that time and training were the largest barriers to technology integration (Kleiner et al.). Educators sometimes find themselves in a position where they are willing to implement technology innovations in their classrooms, yet they lack the necessary skills to do so. Compounding this problem is the amount of time and effort these teachers perceive as necessary to invest in order to learn the appropriate skills to make such technology integration useful to them.

It may be helpful to draw from the large body of work surrounding tacit knowledge and ask the question: to what extent is meaningful teacher use of technology tacit knowledge? Tacit knowledge, as opposed to explicit knowledge, is what a person may know but be unable to transfer to another person by verbalizing it. For example, explaining the rules of Ultimate Frisbee to someone is an example of explicit knowledge. Tacit knowledge, however, might be characterized as the ability to organize and run a successful intramural frisbee league. One might attempt to verbalize the skills necessary to do so but would not be able transfer all the necessary knowledge needed in order to be an expert practitioner. Because of the difficulty of transferring this kind of knowledge, some have proposed that it could be possible to lose our ability to produce certain inventions like the atomic bomb because of the high levels of tacit knowledge associated with complex systems like bomb design (MacKenzie and Spinardi). Education researcher Bruce Torff writes about tacit knowledge in teaching practice, calling the expert implementation of a certain pedagogy a kind of tacit knowledge.

Researchers have start investigating this question of technology adoption and teacher

knowledge. In a 2000 study, researchers surveyed over 400 teachers regarding 67 computer related competencies that related to teaching. Competencies ranged from the 'simple' task of using email to the more complex skill of curriculum integration with technology. Teachers, when asked, generally agreed on the importance of the competencies (Scheffler and Logan). While the results of this study may not seem profound, they represent a first step toward an examination of teacher skills surrounding technology use. The learnings gleaned from these examinations can be applied to the development of knowledge systems and the design of professional development that can assist in the capture and transfer of this knowledge.

An Indiana University study dig deeper and offer some preliminary answers to questions about tacit knowledge. 'LevTech', short for Leveraging Technology to Keep America Competitive, is a \$3 million project funded by the U.S. Department of Education, Office of Educational Technology whose purpose is to focus on current research in the use of technology in education. Specifically, this study will ask questions about the gaps between the technology skills and experiences pre-service teachers (teachers in training) acquire as part of their teacher education programs, the technology skills and experiences that practicing teachers utilize and find meaningful in their classrooms, and the ways pre-service teachers are being prepared to use technology. The study aims to find a way to bridge the gap between experienced and pre-service teachers in technological instruction and learning practice (LevTech).

Attempts to capture tacit knowledge and transform it into explicit knowledge are difficult. Studies like the one being done at Indiana University could further our understanding of the necessary teacher knowledge for successful ICT use in classrooms. We might then be able to use this understanding to inform design of teacher training and professional development.

A Framework for Future Research

Up until now, this paper has explored the area of ICT adoption in education. We have reviewed the history of the issue as well as current research in the area. In this section, I make some suggestions about the nature of the problem and how we can go about researching this area as well as designing systems for teachers.

While extensive deployment of technology was successful in the past two decades, teacher integration of ICTs into teaching practice has not been widespread. Policymakers set, in their eyes, reasonable and achievable standards, but seemingly only a small number of teachers have emerged to leverage ICT for student achievement. In standard diffusion models, the earliest adopters are often opinion leaders and are able to influence the early majority and eventually the late majority to adopt an innovation (Ryan and Gross). However, the group of innovators and early adopters of ICTs in education failed to influence the other individuals in the social system to the point of widespread adoption.

What are some possible reasons for this? Earlier in this paper, I reviewed some factors researchers have found to be likely to explain such widespread ICT non-adoption or refusal in education. Here, I'd like to propose some possible explanations that could be explored in future research.

The social climate of education networks may be such that make it difficult for innovators and early adopters, otherwise opinion leaders, to exert their influence on others in the education system. While further research could be done on the climate of education communities and their receptivity to innovation through innovators and early adopters, it is possible that large numbers of veteran teachers, whose teaching practices have stiffened over time, developed a higher threshold for innovation. Adoption of such innovations would disrupt their current teaching practice, and would need to overcome the inertia of many years spent refining their practice. Additional research in this area might speak to the current debate over the importance of the nature and the structure of networks. Two

different schools may have similar looking networks, with roles and ties that are easily identified between them, but experience a very different process of ICT adoption depending on the climate at the school.

Early adopters, unable to influence the education community at large, developed communities of practice in order to support their own use of ICTs in their classroom. These communities sometimes developed organically with the help of ICTs. But it was often the case where systems were designed specifically to foster collaboration and communication among members of diasporatic ICT inclined teachers (Schlager and Fusco). As the two groups of ICT practitioners and a community of ICT non-practitioners emerged during this time, I propose that both networks become more rich in intra-network connections but become poorer in inter-network connections. In other words, they became homophilic toward members of their community of practice and heterophilic toward. The close nature of these networks may have prevented widespread negotiation of use by the education community and the diffusion of education ICT innovation (Rogers). This negotiation only happened within the social network of the ICT practitioners themselves; any innovation was only able to spread through their network.

Future systems should be designed to lower the threshold of adoption for the early and late majority. As innovation often occurs in heterophilous environments (Rogers), when crossroads or bridges are formed between these two communities, widespread adoption may occur. Research and design should take the following under consideration:

1. Practice shapes learning. In *The Social Life of Information*, Brown and Duguid analyze the ways in which information technology supports or fails to support professional learning. They define failure as the neglect of the ways people learn, resourcefulness in solving practice, and the communities of practice in which they participate.

2. There is no X factor. The idea that there is a single factor or single set of factors is a

simplistic view of the mechanism of development (Adleman). It may be possible to trace system design along a path of attempts to find and solve for X. Both ICT use and education are embedded in a complex array of factors. The process of adoption and leveraging ICTs for student achievement is most likely a non-linear one.

3. Strengthen crossroads locally. The local support community should be viewed as the context and catalyst for ICT adoption and co-evolution (Schlager and Fusco, Zhao and Frank).

4. Allow for existing structures. Stakeholders must be involved during the cycles of ICT adoption, training and use. This should be done in small teams within a school, allowing for existing networks, teacher collaboration and knowledge sharing, avoiding imposition of change of teacher practice or pedagogy. Professional development should foster communities of practice in order to increase meaningful adoption.

Conclusion

Understanding the success or failure of any ICT project is a difficult undertaking. This task is compounded within the field of education because of the complex relationships between the following groups: students, parents, community members, teachers, administrators, policy makers. This paper seeks to trace current research and policy in an attempt to understand the extent to which teachers have potential for impacting student achievement through ICT use. We should understand the relationship between the social context of teachers and ICT interventions because it may help explain why education technology has not been an agent of reform to the extent many expected.

Recently, researchers and education technologists have begun to understand education technology in a more nuanced way, that they may need to understand its relationship with other factors like school leadership and the demands of day-to-day classroom practice (McMillan). However, a more

comprehensive discussion of the role of teachers when implementing an education technology intervention is needed. This paper seeks to propel research on the social context of teachers during an ICT intervention forward. Furthermore,

I propose that by further researching the social context of teachers during an ICT intervention. Specifically, I suggest closer study of the extent to which teacher networks of ICT practitioners and non-practitioners are closed, preventing extensive adoption and the spread of innovation. Finally, I present a few principles to follow during the development of any process that addresses adoption of ICTs in the education community.

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