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CO-EVOLUTION: THE DYNAMICS OF TECHNOLOGY USES IN SCHOOLS

By

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ABSTRACT

CO-EVOLUTION: THE DYNAMICS OF TECHNOLOGY USES IN SCHOOLS

By

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From an ecological perspective, this study investigates the dynamic process of technology use in schools. Participants were 133 students and 20 teachers in a middle school which launched a laptop project in 2003-2004 academic year. Data were collected through three approaches: pretest-posttest surveys, classroom observations and interviews.

Results suggest that technology use evolves. It is a complex ongoing process influenced by continuous interactions between technology uses, the users, and the environment. Seven different evolution paths of technology uses were identified, and the conditions and factors influencing the changes of technology uses and their relationships were illustrated through quantitative data analysis results and specific case studies.

A final model was developed to illustrate the overall picture of technology use in schools. It revealed that the interactions and mutual influences between technology use, the users and the environment are not simple and linear, but are built upon circular causality and reflexivity. Technology adoption is a cycle of changes, co-adaptation, and co-evolution. Analyses on the quality and quantity of technology use suggested that different technology uses have different impacts on student outcomes. Therefore, the

quality of technology use is a critical issue. "How much" matters when "how" is identified.

Results from this study shed light on the dynamic nature and process of technology use in schools and conditions for effective technology uses; they thus have both theoretical and practical implications in that not only is a research gap in technology integration in schools partially filled, but teachers and students can also discover from these results ways to use technologies meaningfully in teaching and learning. Specific implications for policy making, technology integration in schools, professional development and future research are suggested.

DEDICATION

To my parents, LEI DE-WANG (雷德望) and WU ZU-FENG (吴祖凤)—your unconditional love and support gives me strength to stride in life!

To my husband, QIU WANG (王秋)—for loving, supporting and believing in me and my dreams!

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CHAPTER 1

INTRODUCTION

Information technology is developing rapidly and deeply influencing every aspect of our daily lives. In recognizing information technology's limitless potential, combined with an enduring faith in the power of education in making a better society and solving individual and social problems (e.g. Berliner & Biddle, 1995; Tyack & Cuban, 1997; Cuban, 2001), streams of money have been poured into schools in the last two decades to provide technology infrastructure, software and staff training for technology use. Many educational policies and government documents have been publicized and implemented in order to ensure that schools reap the profits provided by information technology. However, despite great enthusiasm from educators, policy makers, parents and the public - along with easily accessible technology training and support and greatly improved technology access - technology innovations remain unused or underused in schools (Cuban, 2001; Zhao,2003).

The slow adoption of technology in schools has been a serious concern of educators and researchers (Berliner & Biddle, 1995; Tyack & Cuban, 1997; Cuban, 2001; Zhao, Pugh, Sheldon, & Byers, 2002; etc.). Great efforts have been made to investigate how technologies are used in schools (Collis, Knezek, Lai, Miyashita, Pelgrum, Plomp, & Sakamoto, 1996; Ager, 1998), why technologies are not used in schools (Cuban, 2001; Schofield, 1995), what conditions influence teachers' technology use (Zhao, et.al, 2002; Zhao & Frank, 2003; Becker, Ravitz, & Wong, 1999; Harris & Grangenett, 1999; Honey & Moeller, 1990), how technology innovations are integrated or rejected (Bruce, 1993;

Cuban, 1986; Tan, Lei, Shi, & Zhao, 2003; etc.), how technology innovations transform and are transformed by existing practices (Bruce, Peyton, & Batson, 1993; Schofield, & Davidson, 2001) , and what teachers need to know in order to use educational technology (Margerum-Leys, & Marx, 2003; Zhao, 2003; Urban-Lurain, 2003) However, given the complicated nature of school systems and technology innovations, the process of technology integration remains elusive to educators and researchers. Although research has identified a long list of factors that could affect technology integration in schools, these factors "are often examined in isolation of each other or the system in which they interact" (Zhao & Frank, 2003). Technology is often treated as an independent artifact or a distinct event. This limitation "makes it difficult to see how changes to a social system occur through other than simple, one-directional causation. This impedes both the development of successful innovations and the understanding of social change" (Bruce, 1993).

It is important, therefore, to gain an understanding of how technologies are used in schools, why some technology uses are popular while some others are not. Discernment of how different technology uses emerge, interact with the system, and develop - and what conditions influence this process - is crucial in helping teachers and students not only use technologies, but also use them in meaningful ways for teaching and learning.

From an ecological perspective, this study views technology use as an ongoing process in which different technology uses are introduced into school systems, interact with social contextual factors and thus are either adopted, reinvented, or rejected. Users will be studied change agents that have the potential to interpret technologies and re-invent them to fit their goals and practices within the affordances and constraints of the social context. Specifically, based on data collected from a laptop project in a middle school, this study asks the following research questions:

1. How do technology uses in schools change overtime?
2. What factors influence the development and popularity of technology uses?
3. How do technology uses affect, and how are they affected by, schools?

Defining "Technology Use"

This study focuses on diverse technology uses rather than specific technologies. "Technology use" is the application of a technology function in solving practical problems (Zhao, 2003). It is different from specific technologies in a few ways: First, a technology is an artifact, a product, and a tool. It has the capacity to solve certain problems, but this capacity is not realized unless it is connected with specific problems, while technology use is the process of connecting this capacity with a practical problem. For example, the Microsoft Word program has the capacity of composing, but this is realized only when users use it to write a paper under certain contexts to solve their problems or achieve certain goals is it a technology use.

Second, technology is situated in isolated and independent artifacts, while technology use is situated in context and connected with users. "The same technology has different meanings in different settings" (Bruce, 1993). It can be used differently, by different people and in different contexts to solve different problems or to achieve different goals (Zhao, 2003). For instance, the Internet has the capacity of supporting communication, and e-mail, online chatting, video/audio conferencing, and discussion board message-posting: all are different applications of a single function and thus are different uses of Internet.

Third, technology is a final product in a static stage, while technology use is in constant change. Users may re-invent a technology to solve their current problem or to fit it to the context, and the change in the technology use may in turn lead to further changes in the users and/or the context. Change begets change. The interconnection and mutual influence between technology use and its context could arouse cascades of changes, and consequently often result in "moving it far beyond what was originally envisioned" (Peyton & Bruce, 1993).

Fourth, technology has one single form. When it is used differently by different people and in different contexts to solve different problems or to achieve different goals, the original technology takes on multiple forms (Peyton & Bruce, 1993). Hence, a single technology develops into multiple technology uses.

In summary, technology use is technology-in-context. Examining technologies from this perspective allows for examination of the specific contextual factors that affect technology use and, potentially, insight into the holistic process of technology use.

CHAPTER 2

THEORETICAL FRAMEWORK

As a saying goes, "The forest is more than a collection of trees." To understand and properly manage a forest we must not only know about trees, but we must also study the forest as a whole (Odum, 1975, p.5). To better understand what conditions influence technology use in schools and how technology use affects schools, we must investigate potential conditions and interactions within a framework.

Researchers have argued for the ecological perspective as one useful approach to holistically capture the dynamic nature of technology use in school settings (Zhao & Frank, 2003; Nardi & O'Day, 1999; Bruce & Hogan, 1998; etc.). For example, Zhao and Frank (2003) argue that a school and its classroom can be viewed as an ecosystem within which the characteristics and roles of different species continuously affect one another and constantly change their relationships with one another. Bruce and Hogan (1998) also argue for an ecological perspective in examining technologies because most technologies become so enmeshed in daily experiences that they "disappear", so only an ecological perspective can give us a basis for understanding the interpenetration among technologies, human beings, and the context within which they interact.

The concepts and mechanisms of an "ecology" are well-articulated by Odum (1975, 1997). The term "ecology" means the study of the earth's "households" including the plants, animals, microorganisms, and people that live together as interdependent components, or "the totality or pattern of relations between organisms and environment" (Odum, 1975, p.3-4).

Main Concepts of Ecology

A fundamental concept in ecology that enables the holistic study of both parts and wholes is *hierarchy*, a way to arrange things into graded compartments. Ecosystem is the lowest level in the ecological hierarchy that has all the necessary components for functionality and survival over the long term (Zhao & Frank, 2003). Ecosystems contain both abiotic and biotic components. The abiotic part of an ecosystem refers to its inorganic characteristics, while the biotic component of an ecosystem is composed of populations of organisms or species. A species must have a *habitat* - the place where an organism lives - and a *niche* - the role of the organism or species in the ecosystem. The biotic component of a functional ecosystem has many *species*, each playing a unique role and occupying a unique habitat. The most important species in an ecosystem is called *keystone species*, which exert some controlling influence over the system (Odum, 1997).

The Mechanism of Ecosystems

An ecosystem is not a stagnant system. On the contrary, it is a dynamic system in constant change, and its changes are systemic. The species interact with each other, coevolve, and maintain the equilibrium of the system.

Coevolution

Another important characteristic of an ecosystem is that different parts *coevolve,* changing together according to the relationships in the system: "coevolution involves reciprocal natural selection between two or more groups of organisms with close ecological relationships but without exchange of genetic information between the groups." (Odum, 1997, p.241). In a social ecology filled with people who learn, adapt and create - even when tools remain fixed for a time - the craft of using tools with expertise and creativity continues to evolve, and the social and technical aspects co-evolve (Nardi & O'Day, 1999, p. 53).

Co-evolution occurs through interactions between organisms, species, and the environment. There are three main types of interactions in an ecosystem: "...either one individual with another of the same species, or with those of distinct species, or with the physical conditions of life" (Darwin, 1956, p.20). Within species, interactions are likely to be influenced by population density - population size in relation to a unit of space. Some species' population growth is inversely density-dependent and they tend to level off in density before saturation. Competition can happen within species or between species when two organisms/species strive for something that is not in adequate supply for both of them. The competition results in two general phenomena in an ecosystem: first, closely related organisms often do not co-habit the same place, or if they do, they occupy a different niche; and second, where a large number of related species is present in a region, the niche of each is often narrower than when only a few species are present (Odum, 1975, p.134).

Interactions can be either negative or positive in terms of their effect. Negative interactions are those by which both parties are hampered in some manner, known as *mutual inhibitions*. Positive interactions can happen in three forms: *commensalisms* - one species benefits and the other is not affected to any measurable degree; *protocooperation* - both species benefit each other, but are not essential to each other for survival, and *mutualism* - the association is necessary for the survival of both species (Odum, 1975, p.141)

Equilibrium

An ecosystem has the *homeostatic mechanisms* that maintain internal equilibrium through interactions and co-evolution. When a new species is introduced into an ecosystem, it interacts with one or more existing species and the environment. For instance, the new species may compete with existing species for resources to develop. Thus the equilibrium is broken, and the homeostatic mechanisms will work to re-achieve equilibrium. Species work in a complementary manner in an ecosystem. For example, when one species slows down, another may speed up in a compensating manner to maintain the equilibrium (Odum, 1975, p.7). In this sense, a new species is an invading species when it is introduced into an ecosystem. Similarly, technology uses introduced to schools are a kind of "invading species." Whether they can be successfully adopted and become permanently established depends on the nature of the invading species and its compatibility with the teaching environment (Zhao et.al. In press).

The Application of Ecological Theories in Education

Ecological theories have been employed by many researchers in social science to study phenomena involving human beings. For example, Bronfenbrenner (1979) describes social environments as multileveled and characterized by micro- and macro-social "nested structures, each inside the next, like a set of Russian dolls." (p.3) and he points out that the microsystems were often the contexts of paramount importance. Rodkin and Hodges (2003) investigate how bullies and victims fit into their peer ecology and define peer ecology as "that part of children's microsystem that involves children interacting with, influencing, and socializing one another" (p.385).

The ecology conceptual framework has also been borrowed by researchers in the field of education. For instance, Keiny (2002) argues for "ecological thinking" as a new approach for studying educational changes. She points out that the two traditionally dominant models for studying educational changes - "top-down" and "bottom-up" models - are based on linear thinking, which implies cause and effect, while an ecological vision of educational changes is built upon circular causality, reflexivity, and interactions. A school system can be viewed as consisting of subsystems, such as teachers, students, and researchers. These components are connected with and influence each other, and education is an "organic" system that promotes growth and development.

From an ecological perspective, Zhao and Frank (2003) investigate relationships among the factors that have already been verified as related to school technology uses. In order to construct a unifying ecological framework that is useful for analysis of technology uses, they establish four metaphorical equivalents between technology uses in schools and ecological issues: a) classrooms - the habitat - as ecosystems; b) computer uses - niche - as living species; c) teachers as members of a keystone species; and d) external educational innovations as invasions of exotic species. Their findings suggest that the ecological perspective can be a powerful analytical framework for understanding technology uses in schools.

This study will examine technology uses from an ecological perspective. As Zhao and Frank maintain, a school system can be viewed as an example of an ecosystem. First, it is a combination of diverse parts and various relationships. It consists of abiotic components such as school buildings and classroom equipment, and biotic components such as students, teachers, administrative staff, technology staff, a school board, etc.

These species are closely connected to each other and the relationships are very complex. Second, a school system has many different resources and materials and allows for individual species' proclivities and interests. Third, the social and technical aspects of the school system interact with each other, influence each other's development as new ideas, tools, and activities arise and thus co-evolve. Fourth, technology use can be viewed as a species because, like any other species, it has a niche - the role it plays in a school ecosystem: to help learning and teaching. It needs resources to grow - money, technology support, training, etc. It interacts with other species - it influences how teachers teach and how students learn, and also impacts school social relationships. It evolves - through interactions with other species and the environment. It evolves from initial use to realized use. Fifth, an ecosystem is marked by the presence of the key-stone species whose presence is crucial to the survival of the ecology itself (Nardi & O'Day, 1999). In the school ecology, the key-stone species are technology users - teachers and students, the most important and essential components of a school system. Without teachers and students, a school ecosystem no longer exists. Furthermore, teachers and students determine (although they may not be able to decide) what the school ecosystem is for and how it should work. In the process of using technology in teaching and learning, teachers and students determine whether, what, and how technologies are used and thus play a crucial role in technology integration.

In the school ecosystem, after a technology innovation is introduced into the system, different users apply it idiosyncratically to solve different problems; this can result in different technology uses. Specifically, in this study, teachers and students use laptops in a variety of situations. For example, teachers use the laptops to prepare lesson plans, to deliver curriculum content, to communicate with colleagues, parents and students, and students use the laptops to do homework, to take notes, to play computer games, and so on. Therefore, with the introduction of laptops, a variety of technology uses are derived and introduced into the school system.

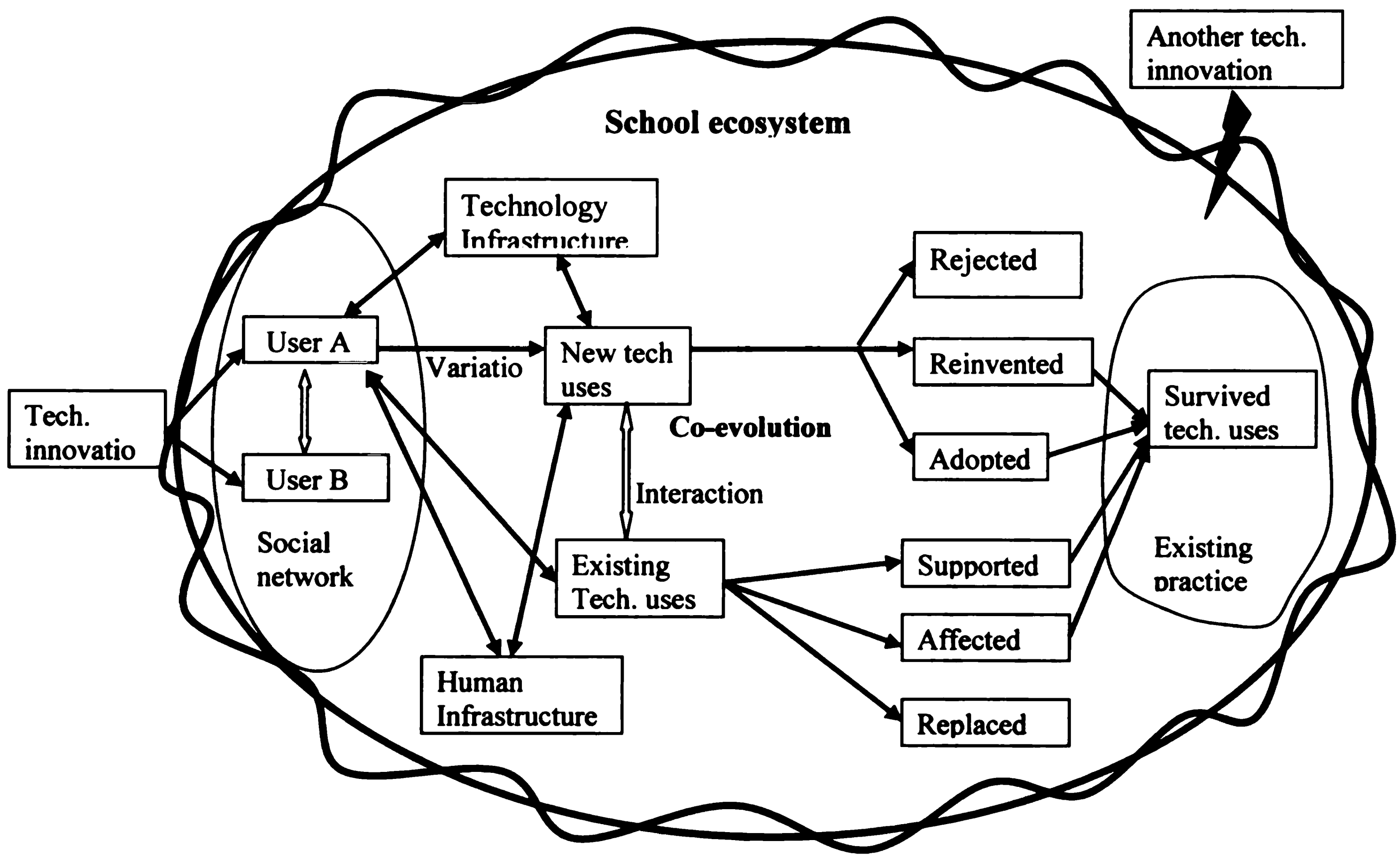
As mentioned previously, there are existing species in the school ecosystem, such as existing technology uses, teaching and learning practices, teachers, students, administrative staff, etc, and the abiotic components such as the classroom equipment and various technological resources. This ecosystem is in a dynamic equilibrium. When a new technology use is introduced into the system, it usually affects both informal and formal activities (Nardi & O'Day, 1999, p.17), and it may also affect the social relationships of existing species. The original equilibrium is very likely to be broken, and this invading species interacts with existing species in the host environment. It is hypothesized that the dynamic nature of technology use resembles that of an ecosystem. For example, within-species competition can occur when two or more technology innovations are present. Each of them competes for resources, support, students' time and energy, etc. When enough technology innovations are present - when population density is high - it can be very difficult to introduce new technologies because population growth will be inhibited. When there are many technology innovations, each of them might play a less important role than when there are only a few, or a few of them play important roles while others are not used very often. Negative interactions could happen when two technology innovations compete for resources, or technology innovations and other learning activities compete for resources; and positive interactions could happen in situations such as those in which the knowledge of one technology use facilitates the use of the other. Species can also co-evolve in this system. For instance, students might change their learning practice because of new technologies, and their learning practice might also influence how they use technology. Thus both their technology use and learning practice evolve together.

The invading species may also be reinvented to fit other species' needs in the process of its adoption and implementation. Rogers points out that re-invention is often beneficial to the innovator because the flexibility in the process of adopting an innovation may reduce mistakes and encourage customization of the innovation to fit it more appropriately to local situations or changing conditions, and that after re-invention, a technology use may be more appropriate in matching an innovators' preexisting problems and more responsive to new problems that arise during the innovation-decision process (1995, p.177). This statement is supported by a national survey of innovation in public schools, from which Berman and Pauley (1975) found that when an educational innovation was re-invented by a school, its adoption was more likely to be continued and less likely to be discontinued.

Therefore, interactions can have three consequences: first, the new technology use fits in the ecosystem well and is adopted; second, the new technology use is reinvented to fit the local environment; and third, the new technology use cannot fit in the local environment and/or cannot be reinvented and thus is rejected. A new dynamic equilibrium will be achieved. The reinvented and adopted technology uses will co-evolve with existing species and be integrated into this ecosystem until the new dynamic equilibrium is broken by other new invading species and these existing species are changed or replaced by other technology uses. Figure 1 illustrates the process of how a technology use develops in a school ecosystem.

Technology use in an ecosystem is a process of negotiation among the species. These species have different goals, which make them react to the same technology in different ways; but they also have shared goals and shared approaches, which make them work together and co-evolve. During the process of conflicts and cooperation, a technology use can be accepted and become popular, or accepted marginally, or rejected. Based on literature review of related research studies, the following section discusses factors that may influence this process of negotiation in an ecosystem.

Figure 1: The Evolution Of Technology Use In The School Ecosystem



CHAPTER 3

ANALYTICAL FRAMEWORK

--Factors Influencing the Dynamics of Technology Uses in Schools

To identify the factors influencing how different technology uses emerge and evolve in the school system, a detailed analytical framework was developed through literature review. In a study investigating conditions for teacher technology use, Zhao et al. (2002) categorize the conditions influencing teacher technology use into three domains: the innovator, the innovation, and the context, a useful classification. This study will follow this categorization, but rename the categories as the key-stone species (the users), the invading species (technology uses), and the ecosystem environment (the context), in order to analyze factors influencing technology uses in schools.

Factors Related to the Invading Species

The characteristics of the invading species play a vital role in its survival in the hosting environment. Technology uses in this study are the invading species to an ecosystem. Technologies differ greatly in many ways, such as the problems they can solve, the resources they need, and the complexity of skills needed, etc. Based on literature review, this study will focus on the following aspects of a technology (use): the niche, compatibility, complexity, relative advantage, and innovation-decision making.

The niche

In natural environments, species differ in their niches. Some species are more flexible and function differently in different habitats, and some are less flexible in the roles they play. Species also vary greatly in the breadth of their niches and hence can be categorized as specialists and generalists (Odum, 1975, p.). Odum (1975) points out that specialists are often more efficient in the use of their resources and therefore often become very successful when their resources are ample. However, while specialists are more vulnerable to changes, generalists allow more chance for variation since their niches are broader and thus have increased probability of being adopted: "the more diversified the descendants become, the better can they seize on places in the polity of nature, and so increase in numbers....The more diversified the descendants become, the more places they will be enabled to occupy" (Darwin, 1965, p.34).

Just as species in natural ecosystems vary greatly in the rigidity and breadth of niches, technologies vary both in their rigidity and breadth of uses. The broader the niche, the more flexible a technology use is, and vice versa. Some technologies can be used in different environments and for different purposes, such as Microsoft Word. Some are more fixed, such as e-mail software. There are both advantages to and limitations of specific and generic technologies. A specific technology could be easily adopted in that the specificity helps users make the connection between the tool and the problem, but may also be easily rejected if the niche is occupied by other technologies. On the other hand, a more generic technology may not be very explicit in making a specific connection with a problem, but it allows for more creativity (Zhao, 2003a), therefore it leaves more room for variation which increases the possibility of reinvention and adoption.

Compatibility

A specific technology use must be compatible with the whole ecology, both from a technical dimension and from an ideology/epistemology dimension.

Specifically, the compatibility of a technology use includes the following aspects: First, *the compatibility with existing school culture.* Some technologies may be incompatible with school policy or people's (particularly adults') beliefs. If one type of technology use is inconsistent with the school district policy, it's is very likely to be banned. For example, chatting online is prohibited in some schools because parents and teachers are afraid of the risk of communicating with strangers for students. Playing computer games is another example that conflicts with the school district policy in some schools. Second, *the compatibility with existing practice.* Compatibility with existing practice includes how technology applications fit into ongoing classroom practice and the already established curriculum. Researchers have pointed out that there is a mutual influence between technologies and the existing practice in the context. On the one hand, technologies are usually used to facilitate existing practice instead of fundamentally change it (Schofield, 1995, p.104). On the other hand, "The already functioning social system and traditional practice which the technology is placed shape the ways the technology is understood and used" (Bruce, 1993). Miller and Olson (1994) argue that teachers' practice and experience influence how teachers use technology and how they incorporate new tools and new symbols into their teaching culture. Therefore, the more compatible a technology use is with existing practice, the more likely it will survive. Third, *the compatibility with available technological support.* If a technology use requires technology resources and human technological support beyond the control of the innovators, it is less likely to succeed.

Complexity

Complexity is "the degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 1995. p.242). Meaningful technology use should be not only intellectually challenging but also apprehensible. If the technology innovation is too complex, users are less likely to use it. In the early days of microcomputers, the command line interface was difficult to comprehend, making it necessary to attain a certain mastery simply to use its functions. So these machines were, by and large, only accessible to experts and "hackers." The popularity of personal computers since the 1980s can largely be attributed to the development of user-friendly GUIs (Graphical User Interfaces), which lowered the complexity of the machines and thus made them more accessible and understandable for the general public. In a school ecosystem, the complexity of technology use should be compatible with teachers' and students' technology skill levels. Research suggests that the perceived complexity of a technology innovation is negatively related to its use. For example, in a study investigating what technology innovations were selected and what were discarded in a technology-rich environment for middle school students, Tan et al. (2003) find that technology innovations that are recreational and require less complex skills are more likely to be initiated and/or selected by students, and are more likely to be used more frequently. Technology uses that are compatible with users' current technology proficiency level and share some similarities with users' current technology uses are viewed as less complex and also easier for users to make connections between the technology and their problems or needs.

Relative advantage

Relative advantage is the degree to which an innovation is perceived as being better than the idea or practice it supersedes (Rogers, 1995. p.212). Relative advantage can consist of economic benefits, social prestige, social acceptance, or other benefits. Sometimes the early adoption of a technology innovation confers social prestige, but later with the spread of that technology innovation, its adoption becomes a necessity (Pleto, & Muller-Wille, 1972). The relative advantage of adopting a technology innovation is equivalent to the relative disadvantage of not adopting it. The quick spread of cellular phones in China in recent years was to a great extent pushed by the pursuit of social prestige and not wanting to be "left behind". The motivation of some school districts to install computers and Internet access may be attributable to a desire to build a good school image and have a good reputation because technology use has symbolic meanings. In addition, innovations are more likely to be adopted when the expense of adopting new methods and tools is justified by the major improvements they bring about.

Innovation decision-making

How technology innovations are introduced into the school system may also have an impact on their success or failure. Rogers (1995, p.372) identifies three types of innovation-decisions: 1. Optional innovation-decisions. The decisions to adopt or reject are made by individuals and are independent of decisions made by other people. 2. Collective innovation-decisions, in which the choice to adopt or reject an innovation are made by a consensus among members of a system. 3. Authority innovation-decisions, choices to adopt or reject an innovation made by a few individuals in a system who possess power, status, or technical expertise. Different decision-making approaches have different effects on whether and how the technology innovation is adopted. Tan et al. (2003) find that activities initiated by students - the key-stone species in that ecosystem - are more likely to be adopted. However, in the school ecology, usually it is the technology experts, board members, or principals who decide to choose specific technologies, while the key-stone species - the teachers and students - seldom have a say in the decision making processes. For example, when trying to examine who was pressing for increased computer education in the 1980s, Besser (1993) found that the key forces advocating computer education were corporate managers, higher education leaders, social/technology community members, military personnel, the federal government and media: teachers were not among these forces. As Cuban (1986) points out: "The technology and its initial applications to the classrooms were conceived, planned, and adopted by nonteachers.... School boards and superintendents initiated efforts for using the new technology; only later were teachers involved in discussions of how to install it into the classroom" (p.36).

Factors Related to Ecosystem Environment

The hosting environment is the context in which the innovation is introduced and interacts with existing species. Research indicates that the context not only influences how technologies are used, but also has a strong mediating effect on the success (or failure) of technological innovations (Schofield, 1995; Zhao, et al., 2002). Specifically, the human infrastructure and the technological infrastructure of a school ecosystem are crucial to the success or failure of a technology use.

Technological infrastructure

Technology infrastructure includes quantity (availability) and quality of hardware such as computers and Internet access, availability of software, and the ease of accessibility to both hardware and software.

Hardware-quantity of access. A basic condition for student technology use is access, which includes technology access in school and at home. When computers are viewed as expensive machines that should only be accessed by experts, there can't be much student use. For example, based on the International Association for the Evaluation of Educational Achievement Computers in Education Project (IEA

CompEd), Pelgrum and Plomp (1996) found that before 1992, there was little integration of computer use in the curriculum of schools. Computers were mainly used for computer education courses, typing classes, or similar technical ("drill and kill") activities. Although there was somewhat more integration of computers into the curriculum in 1992, overall, the use of computers in existing school subjects remained limited. In the past 15 years, great efforts have been made to equip schools with information technologies. As a result, the overall student-computer ratio in K-12 schools has dropped from about 168.0 to 6.0; i.e., there are now 6 students for every computer (Anderson & Ronnkvist, 1999). More access to computers provides the possibility for more computer use.

Technology access also includes access outside of school. Pelgrum and Plomp (1996) found that students learned much about computers outside the school. Home technology use can also facilitate teachers and students' technology uses in school.

Easy availability. However, Zhao et al. (2002) point out that access is different from easy access. Only when teachers and students have easy access to computers, can they use technologies easily and meaningfully. Teachers are more likely to use technologies when these technologies are available to them, available in their classrooms as opposed to computer labs, and available in greater numbers. Additionally, teachers who had more computers available in the classroom were generally more likely to report assigning students to use various technologies to conduct various tasks (U.S. Department of Education, 2000; Becker, 2000; Becker, 2001). Becker's (2000) results show a strong relationship between how frequently technologies are used during class time and whether there is a substantial number of computers available in the classroom. However, according to one survey conducted by the National Center for Education Statistics (NCES), although 84%t of public school teachers had computers available in their classrooms, only 48 percent of the teachers surveyed reported having more than one computer in their classrooms (U.S. Department of Education, 2000). Becker (1999) also points out that although public school Internet access increased from 35% in 1994 to 90% in 1998, only 39% of 4th-12th grade teachers had some kind of Internet access in their classrooms (Becker, 1999), and one-half of all school computers remained in rooms that are separate from where regular classroom instruction occurs (Becker, 1998). The separation of computers from classrooms makes it difficult for teachers to seamlessly integrate technology use into teaching activities.

Quality of available hardware. Quality of available technologies may be another factor influencing school technology use. Anderson and Ronnkvist (1999) point out that although the presence of computers and the Internet has grown sharply in recent years, much of the technology equipment currently in schools and classrooms is from an earlier generation of technology - computers with less processing power, less storage capability, and limited capacity for being linked together electronically. Using contemporary standards for home and office computers, over half of the computers are out of date. And in elementary schools almost two-thirds are of limited capacity (Anderson & Ronnkvist, 1999). About one-half of the computers available in schools lack a modern operating system and are not able to run multimedia applications efficiently (Anderson & Ronnkvist, 1999; Becker, 1998). Furthermore, as current technology continues to advance at a tremendous rate, it is increasingly difficult for schools to "catch up with the moving train" (Becker, 1998). Therefore, the quality of available technology infrastructure influences not only how much technologies are used in schools but also how they are used.

Software. Good instructional software/courseware can reflect research on how students learn, align with national, state, or district educational standards, and be integrated into the teaching and learning activities of the classroom. This can, in turn, help teachers make the connection between technologies and their teaching content. However, The California Instructional Technology Clearinghouse has rated only 6 to 8 percent of evaluated courseware as "exemplary," and from 33 to 47 percent as "desirable." Less than half of the courseware submitted to the Clearinghouse had sufficient quality to merit review (Coley, Cradler & Engel, 1997). Without good software, it may be difficult for teachers to see how technologies can help them teach and help students learn.

Human infrastructure

Human infrastructure is “the organizational arrangement to support technology integration in the classroom” (Zhao et al, 2002). It includes technical support staff, administrative staff, and institutionalized policies and procedures related to technology issues. Human infrastructure is the social support users can get from the school system to make as much use of available technologies as possible. As aforementioned, sufficient access to technology infrastructure does not naturally mean sufficient technology use. Burbules and Callister (2000) point out that access issues not only include who can afford a computer or who can get an online connection, but also who can use the Internet and who can operate the software. Users who cannot participate effectively across the full range of opportunities and resources the information technologies provide cannot be said to have “access” (p.19). To help teachers and students fully take advantage of available technologies, a supportive human infrastructure is crucial. Iansiti (1998) argues that applying the right resources, tools, and problem-solving approaches through the organizational process provides enormous leverage for technology integration. Specifically, this study focuses on the following aspects of human infrastructure: availability of technical support, support from administrative staff, opportunities for professional development, promotion of technology use in school policy, and development/technology training opportunities.

Technical support. "Technology is great - when it works". Technologies can solve problems, but they themselves become problems when they don't work. Teachers and students will inevitably encounter technical problems in their technology uses. They are not likely to use technologies in classrooms if it is hard to get technical help or it takes a long time to solve the problems. Therefore, providing sufficient and timely technical support is very important to teacher and student technology use. For example, a full-time technology coordinator may assist teachers with using computer software and hardware or adapting their teaching practice to include technology use. Conversely, lacking timely and sufficient technical support can be a serious barrier to school technology uses.

Administrative support. School technology use also needs administrative support, including strong principal leadership and supportive policy related to technology use. Principal leadership has been identified as one of the most important factors affecting the effective use of technology in classrooms; supportive principals can not only model technology use but also highlight teachers' effort to improve teaching and learning through technology use (Byrom, 1998). Energetic and committed school leaders can transform the entire school ecosystem into a technology-use-friendly environment in which teachers and students feel encouraged to use technologies. In addition, supportive policy is also important in that it ensures an institutional plan in which a philosophy is established, roles are clarified, and an infrastructure is formed to accommodate the efforts of any individual who wants to use technology.

Technology training opportunity. The fact that teachers do not always have opportunities to learn about and practice instructional reforms has been identified as one important factor that contributes to the success or failure of instructional reforms (U.S. Department of Education, 2000). Research also shows that helping teachers learn how to integrate technology into the curriculum is a critical factor for the successful implementation of technology applications in schools (Coley et al., 1997), because "When teachers are not trained to use new technology, computers end up being just souped-up typewriters" (Cuban, 2001). In the NCES survey, teachers who reported spending more time in professional development activities (9 hours or more) were generally more likely than teachers who spent fewer than 9 hours in such activities to report feeling "well" or "very well" prepared to use computers and the Internet for instruction. However, in 1999, only one-third of teachers reported feeling "very well" or "well" prepared to use computers and the Internet for instruction (U.S. Department of Education, 2000). Clearly, it is important to provide technology training opportunities to teachers, either as a part of pre-service teacher education, or as professional development for in-service teachers.

Similarly, technology training is needed to help improve student technology use. Students can improve their technology proficiency through both formal information technology education in school and informal technology education programs such as computer clubhouses. Studies indicate that technology-rich after-school programs are effective in improving participants' technology knowledge and skills, especially on advanced technologies (e.g., Zhao, Tan, Lei, Shi, & Martineau, 2003).

Having time to explore. Research has shown that lack of release time for teachers to learn, practice, or plan ways to use computers or the Internet is one barrier for teacher technology use (U.S. Department of Education, 2000; Zhao, Frank, & Ellefson In press). A supportive context should provide teachers and students time to explore and get acquainted with technology. Experimenting with technologies can help teachers and students in many ways. Papert (1992) suggests that any kind of "playing with problems" will enhance the abilities that lie behind their solution because spending relaxed time with a problem leads to getting to know it, and through this, to improving one's ability to deal with similar problems (p.87). Zhao, Tan and Mishra (2000) state "Children, through active use of technology to solve problems, are in a sense practicing and learning the new literacy brought upon them by new technologies. Their mucking around with new technologies is actually a way to participate in the future." Burbules and Callister (2000) also point out that just "messing around" is an indispensable approach for users at all levels of sophistication, because in doing so, they not only have a chance to work their way out of the problem, but also an opportunity to discover new capabilities of the system they are using. Zhao and Frank (2003) find that teachers reported more computer usage when they had explored new technologies on their own, and thus they suggest schools make the effort to build in "play" time for teachers during the school day, and professional development sessions to build in free time for teachers to explore technologies on their own.

Having freedom of technology use. Research indicates that providing users, especially students, with the freedom to learn with and about information technologies is critical. Generally, in classrooms students don't have the freedom to choose what, where, when, and how they can work on computers. Teachers often see the computers as a tool to help them teach or manage the classroom, but feel uneasy about what students might do with the computers, so students have limited options with new technologies (Bruce, 2000). Zhao et al. (2000) argue that if the students are given the freedom to explore technologies by themselves, they will make creative and productive use of technologies to solve their own problems and work on practical projects. Computers in classrooms can help students learn more and better not only on academic subjects but also on technology knowledge and skills if they are a "children's machine" instead of a "teacher's machine." Hence, freedom to learn with and about technology can be an important factor in school technology use, especially student technology use.

Factors Related to the Key-Stone Species

Key-stone species in this study include both teachers and students. Most studies examining characteristics in school technology integration focus on teachers because teachers have been viewed as the key factor in technology uses in classrooms in that they decide whether, what and how technologies are used in classrooms(Cuban, 1986, Conway & Zhao, 2003, etc.). Therefore, this section will discuss factors that can be applied to both teachers and students first, and then will consider some factors that are unique to teachers.

SES:

The users' socioeconomic status influences how they use technology in different ways, directly or indirectly. For example, research shows that among those with technology available in their schools, teachers in low minority and low poverty schools were generally more likely than teachers in high minority and high poverty schools to use computers or the Internet for a wide range of activities (U.S.

Department of Education, 2000). One explanation for this may be that new technology innovations are usually expensive and only people who can afford them can adopt them and use them (Pelto & Muller-Wille, 1972), so people with higher SES generally have more and better access to technology and thus may have more technology experience and higher technology proficiency.

Gender

Gender may also play a role in what and how technologies are used. For example, Coley, et al. (1997) found that females were more likely than males to have word processing experience, while males were more likely than females to have coursework or experience in computer literacy and computer programming, and more likely to use computers to solve math and natural science problems.

Grade

Research results indicate that grade level influences both teacher technology use and student technology use. The survey conducted by the National Center for Education Statistics (NCES) reported that while elementary teachers are more likely to use computers or the Internet to communicate with parents, secondary teachers are more likely to use computers or the Internet for administrative record keeping, and teachers of fourth-graders were more likely than teachers of eighth-grade students to report that their students used computers to read stories and practice spelling, punctuation, and grammar (U.S. Department of Education, 2000). Another study reports that the percentage of students' technology use for school work almost daily increases as the grade level progresses from 4^{th} grade, 8^{th} grade and 12^{th} grade (Coley, et al., 1997).

Technology proficiency

Since it is up to the users to make the connection between a technology function and the problems they face, technology proficiency is of crucial importance in how technology is used. Zhao (2003a) defines three levels of technology proficiency: mechanic, meaningful and generative, and points out that at different technology proficiency levels, users utilize technologies differently according to their different understanding of technologies. Studies show that many teachers don't use the available technologies because they don't have the corresponding skills and knowledge to use these technologies, and some teachers readapt the technology according to their own technology skill level and their goals. The NCES survey also finds that for many instructional activities, teachers who reported feeling better prepared to use technology were generally more likely to use it than teachers who indicated that they felt unprepared (U.S. Department of Education, 2000). Further, teachers' technology proficiency not only influences how and what technologies they themselves use, but also directly affects how their students use technologies. For example, Becker (2000, 2001) finds that teachers with more computer knowledge are more likely to have their students use more constructive software such as database and multimedia authoring software, than teachers who are less technology-knowledgeable, and the latter have their students use more skill-practice software.

The importance of technology proficiency of teachers and students has been broadly recognized, and in the past few years, technology proficiency standards for students and teachers have been publicized across the country. For example, The American Association of School Librarians and Association for Educational Communications Technology (1998) published *The Nine Information Literacy Standards for Student Learning,* which divided these nine information literacy standards into three categories: Information Literacy, Independent Learning, and Social Responsibility. In 2000, the International Society for Technology in Education (ISTE) developed the National Educational Technology Standards for Students and a National Educational Technology Standards for Teachers. In 1998, nine states had technology standards for teachers and another four were in the process of developing technology standards for teachers (Zhao, et. al., 2003). Based on the most influential ISTE technology standards, technology proficiency evaluation scales were developed in this study to evaluate the technology proficiency of teachers and students respectively.

Social awareness

People who adopt technology innovations are typically faced with a challenging task of resolving conflicts between the constraints of old practices and the imperatives of the new technology (Bruce, 1993). Solving these conflicts is generally beyond any individual's immediate control. The innovators who have a higher/better social awareness know where, from whom, and when to get help, and thus have a better chance to use technology innovations more frequently and more successfully.

Social network

People's social network plays a vital role in their technology uses because, as social beings, they are easily influenced by other people such as supervisors, peers or parents. If the innovator is highly interconnected through interpersonal networks in a social system, he/she is more likely to be exposed to technology innovations, mass media communication channels and interpersonal communication channels, and is more likely to be influenced by innovative people (Rogers, 1995, p.273-274). Social networks can also provide both technical support and psychological pressure for teacher technology use (Zhao, Frank, & Ellefson, In press). Peer influence is an important factor in most people's lives, especially students at the middle school level. They value peers' opinions highly and are heavily influenced by them. If the innovator's peers use technology frequently and/or proficiently, he/she is also likely to use technologies frequently and proficiently, and vice versa. Furthermore, from the social-cultural perspective, cognitive development results from a dialectical process in which a student learns through problem-solving experiences shared with someone else, usually a parent or teacher but sometimes a sibling or peer (OPA). A positive peer environment also helps people explore and accept new ideas and learn new technologies.

Teachers and students also influence each other's technology use. Teachers' technology use not only creates classroom environments that are inclusive and engaging so that the opportunities afforded by technology are used wisely and creatively, but also provides a social supporting environment where students feel encouraged to use technology. Students' technology use can also influence teachers in some ways. On the one hand, technology proficient students can help teachers use technologies in the classroom, which provides teachers with technological support and human support, and at the same time helps to create an encouraging environment for technology use for everyone in the class. On the other hand, students' technology use also makes teachers feel the urgency to catch up in their own technology uses to keep their sense of competency and classroom authority (Schofield, 1995).

Teacher beliefs about technology

Teachers' beliefs affect whether, and to what extent they use technologies. Studies show that teachers are viewed as important agents of change in the reform effort currently underway in education and thus are expected to play a key role in changing schools and classrooms. Paradoxically, however, teachers are also viewed as major obstacles to change because of the conflict between the reform and their existing beliefs (Prawat, 1992). Regarding technological reforms, research has shown that most teachers hold an incrementalist viewpoint on technology uses, which holds that the goal of technology use is not to fundamentally change education practices but to help teachers and students do what they are currently doing more efficiently and effectively (Schofield, 1995, p.104). Russell, Bebell, O'Dwyer, and O'Connor (2003) suggest that teacher beliefs about the importance of technology for teaching are crucial in their decisions to adopt and frequently use technology in classrooms, and it's also an important predictor for teacher-directed student use.

In addition, Zhao et. al. (2002) find that if technologies are viewed as the means to an end rather than an end in itself, successful technology use in classrooms is more likely to happen. When the value of technology is limited to peripheral functions, the likelihood of successful technology use is greatly reduced.

Pedagogical beliefs (teacher)

Teachers' beliefs and understanding of what good teaching is and what the nature of learning is play an important role in classroom technology use. Becker (2001) differentiates two teaching philosophies: traditional transmission instruction, which believes that students learn facts, concepts and understandings by absorbing the content delivered by teachers or from texts and that skills are mastered through practices; and constructivist-compatible instruction, which believes that understanding arises only through prolonged engagement of the learner in relating new ideas and explanations to the learner's own prior beliefs. His study finds that teachers with the most constructivist teaching philosophies are stronger users of computers and they also encourage their students to use computers in their work more. Furthermore, constructivist teachers are also reported to have a greater variety of computer use. The

Office of Technology Assessment of the U.S Congress also reports that some teachers use technology in a traditional teacher-centered model of teaching, while other teachers use technology to support different, more student-centered approaches to instruction. The latter kinds of teachers are among the most enthusiastic technology users, since technology is particularly helpful in supporting this kind of teaching. (U.S. Congress, Office of Technology Assessment, 1995, pp. 1-2). Conversely, teachers who believe in a more traditional transmission-oriented approach will find most technology innovations incompatible with their pedagogical goals and will therefore use a more limited range of technologies (Becker, 2000).

Teaching experience (teacher)

Research has shown that teachers with varying years of teaching experience differ with respect to how and to what extent they use technologies. Generally speaking, teachers with the fewest years of teaching experience were more likely than teachers with the most years of teaching experience to use technologies (U.S. Department of Education, 2000; Russell, et. al., 2003). If we assume that teachers with the fewest years of teaching experience are younger teachers, then this phenomenon may be due to the fact that new teachers have grown up in a technology-rich environment. As they enter the teaching profession, their comfort and skill with technology lead to increased use of computers for instruction. The length of teaching experience also influences how technologies are used. Russell et. al. (2003) find that teachers with less than 5 years of teaching experience use technologies significantly more for instruction preparation than teachers with 15 or more years' teaching experience, but require students to use technology during class time significantly less than more senior teachers.

Teacher perception (teacher)

Zhao and Cziko (2001) argue that teachers must be viewed as goal-oriented, purposeful organisms in order to understand why technologies are or are not used. Teachers have a hierarchy of goals. They use lower-level goals to attain higher-level goals, and the importance of any decision is determined by its capacity to contribute to the achievement of higher-level goals. Therefore, teachers' decisions related to whether, what, and how technologies are used are made based on their perceptions of technology in relation to their hierarchy of goals. Cuban (1986) also argues that teachers' holistic perspective of what is important to students is one of the major resistances to converting classrooms into technical enterprises: "To question computer use in schools is to ask what schools are for, why teachers teach certain content, how they should teach, and how children learn" (Cuban, 1986, p.98). Teachers are not motivated to tackle the challenges of technology uses unless they see how these technology uses will help improve teaching and learning (US Department of Education, Office of Educational Research and Improvement, 1993). Furthermore, teachers' perceptions of barriers to technology use also influence how and to what extent they use technology. For example, teachers who perceived the lack of computers and time for students to use computers as great barriers were less likely than those who did not perceive these conditions as barriers to assign students to use computers or the Internet for some instructional activities (U.S. Department of Education, 2000). Therefore, as predicted by Cuban (1986, p.99) almost 20 years ago, new technologies will be tailored to fit the teacher's perspectives.

Subject taught (teacher)

Research has found that technology use in different classrooms varies. Becker (2000) finds that students in computer classes and business classes use technologies most often, while social studies, math, and fine arts classrooms have the least student technology use. Zhao and Frank (2003) find that teachers of English are especially likely to use computers and that these teachers view computers as a natural tool for student writing activities. Another study reports an interaction between subject area and technology ability in both teachers' and students' technology use (Becker, 2001), and Becker suggests that the difference has much to do with the objectives of teachers in different subject areas and of students with different ability levels.

Outcomes

This study will examine both the quantity and the quality of technology uses with a major focus on the quality. The quantity of technology uses includes the frequency of a specific technology use and the amount of time spent on it. The quality of technology use will focus on four aspects/results of technology use: 1) academic achievement evaluated by GPA; 2) technology proficiency; 3) Learning Habits; and 4) developmental outcomes such as self-esteem, Life skills and attitude toward school.

Student GPA

One of the fundamental goals of integrating technology in schools is to improve student academic achievement. Therefore, the impact of technology use in student academic performance is one major criterion for the quality of technology use. In this study, student academic achievement is evaluated through GPA.

Improved technology proficiency

Meaningful technology use can help improve users' technology proficiency. In the first place, meaningful technology use can help students develop a deep understanding of information technology. As Piaget points out, "To know an object is to act on it. To know is to modify, to transform the object, and to understand the process of this transformation, and as a consequence to understand the way the object is constructed" (Piaget, 1964). Dewey claims that the importance of an idea is to be located in its consequences when they are put to real-world use (1963). Resnick (1987) also suggests that mental activities make sense in terms of their results in specific circumstances. Thus, only through actually using technology can students really understand technology's concepts and functions, because "understanding is developed through continued, situated use" (Brown, et al., 1989). Furthermore, meaningful technology use can also help students understand its context, or the world in which technology is used. "Learning and thinking are always situated in a cultural setting and always dependent upon the utilization of cultural resources." (Bruner, 1996, p.4). In the process of using information technology, students can not only understand the nature of information technology, but also can connect information technology with the context in which technology can be used to solve problems. Thus, in this study, changes in participants' pretest and post-test technology proficiency will be examined as one aspect of the quality of their technology uses.

Learning Habits

Learning habits, or studying habits, are "a set of behaviors related to how students organize their time and space to promote systematic study behavior" (Christensen, Issacs, & Isaacs, 1991). Researchers have studied the importance of learning habits in teaching and learning and how technology can play a role in enhancing student learning habits (Leanmson, 1999). For example, Butler and Cartier (2004) argue that to be successful in an academic arena, students must adopt a working habit that can help them carefully interpret the requirements of learning tasks. Bennett and Diener's study (1997) suggests that properly used, technology can help students enhance their learning habits. Therefore, student learning habits is included as one aspect of student outcomes in this study.

Developmental outcomes

Middle school time is a very important period of development, and academic achievement is only a part of that growth. Technology can provide a variety of experiences for children and youth and may provide them with the opportunity for self-exploration. Researchers have explored the role of technology activities in helping students' developmental aspects such as attitude toward schooling, self-esteem, and life skills (Zhao, et. al, 2003).

Based on above criteria, this study evaluates the quality of technology uses by their impact on student GPA, technology proficiency, learning habits, and developmental outcomes.

Table 1 lists variables investigated in this study. It is important to note that some of the factors may relate to each other. The potential correlation between factors will be considered both in data analysis and result interpretation.

Table 1: Variables Investigated In This Study

	Variables	**Data source/Scale**
Ecosystem	Technological infrastructure 1. quantity of access 2. quality of access 3. Easy availability 4. software	Survey Likert-scale 1-7
	Human infrastructure 1. Technical support 2. Administrative support 3. Technology training 4. Having time to explore 5. Having freedom of technology use	Survey
Key-stone species	SES Gender Grade Tech. proficiency Social awareness Social network Teacher beliefs: technology, pedagogy Teaching experience Teacher perception Subject taught	Survey
The invading species	Niche	Survey
	Compatibility-- *compatibility with existing school culture*	Survey
	Compatibility-- *Compatibility with existing practice*	Survey
	Compatibility-- *Compatibility with available technological support*	Survey
	Complexity	Survey
	Relative advantage	Survey
	Innovation Decision-making	Survey
Outcomes		
Quantity	Frequency	Survey
	Time spent on computers	Survey
Quality	GPA	Survey
	Technology proficiency	Survey
	Learning Habits	
	Developmental Outcomes	

Categorizing Technology Uses

As discussed earlier in this paper, a technology innovation may be adopted and reinvented by different users as species interact and negotiate, and, thus, may take an inexhaustible number of forms which represent realized technology uses. To make the data collecting and analyzing more manageable, technology uses in this study are categorized into groups for teachers and students (Table 2).

Student technology uses are categorized based on Bruce and Levin's (1997) four categories of media: technology use for inquiry, technology use for communication, technology use for construction, and technology use for experience. For example, the same technology, the Internet, can be used in different ways when solving different problems or serving different goals, and the different uses can be put into different categories: using the Internet to search for information is technology use for inquiry, to chat with others is technology use for communication, to build a website about oneself or the school is technology use for construction, and to surf online for fun or to explore is technology use for experience.

Teacher technology uses are classified based on teacher technology use categories developed by Russell and colleagues (2003). Based on survey data collected from 2,894 teachers in 22 school districts, they defined six specific categories of teacher technology use: to deliver instruction, to prepare for instruction, to accommodate instruction, to communicate with others in and out of the school, to direct students to use technology, and to manage classroom such as recording grades. For instance, using PowerPoint to present teaching content is technology use to deliver instruction; using the Internet to search for information needed for a lesson is technology use to prepare for instruction; sending an e-mail to students' parents is technology use to communicate with others, and using Excel to record student grades is technology use to manage classrooms.

Table 2: Categories of Technology Uses

Key-stone species	**Technology use**	**examples**
Students	for inquiry	Internet + research
	for communication	Internet + chatting
	for construction	Internet + web authoring
	for expression	Internet + surfing online
Teachers	to prepare for instruction	Using Internet search for information needed for the class
	to deliver instruction	Using online learning programs
	to accommodate instruction	Using Internet for incidental learning
	to communicate with others	E-mail students, post assignments online, etc
	to direct students to use technology	Guide students to use Internet such as Webquest
	to manage classroom	Using online class management system

CHAPTER 4

METHODOLOGY

This chapter explains the participants, instruments, data collection and data analysis for this research.

Participants

Participants of this study were students and teachers in a middle school in the United States of America. The school is located in a middle- and upper-class neighborhood with about 1% of students receiving free or reduced-cost lunch. The student enrollment was 237, and the teacher-student ratio was 9.1 (2003-2004 school year). The school has extremely rich technology resources: Every classroom is equipped with a computer projector, overhead projector, TV, and VCR, and the whole building has wireless Internet access. In October 2003, the school launched a laptop project which provided a laptop computer for every teacher and student.

Instruments and Data Collection

Data were collected over one academic year through three approaches: surveys, interviews, and classroom observations.

Surveys

Surveys were administered to both students and teachers. Both surveys included pretest surveys and posttest surveys. Pretest surveys were administered at the beginning of the academic year before the laptops were distributed, and posttest surveys were administered at the end of the academic year.

Student survey.

Student pretest surveys included the following sections: 1) Demographic information, such as SES, grade, and gender. 2) Investigation of current technology use, such as how much time do you spend on working on computers very day, what do you use computers for, whom do you turn to when your computer doesn't work, etc. Questions in this section were all multiple-choice questions. 3) Investigation of the key-stone species variables such as their attitudes and beliefs toward technology, perception of technology use, attitude toward schooling, self-esteem, behavior, social network, social awareness, etc. Questions in this section were Likert scale questions using a scale of 1-5. 4) Evaluation on current information technology proficiency. Based on existing literature, especially current student technology standards, one technology proficiency scale was developed to evaluate students' information technology proficiency. Participants were provided with a series of technology situations, and then asked to solve a practical problem by working on a multiple choice question in each situation. 5) Questions related to the context, such as "I have easy access to technology resources such as software", "I can easily get help when my computer doesn't work", "I have opportunities to learn about technology", etc. Questions in this section used Likert scale with a scale of 1-5.

Student posttest surveys included all the sections 1-5 in the pretest survey, and had one more set of questions on variables related to actual technology uses. Based on data collected from interviews and classroom observations, possible technology uses were listed and participants were asked to rate each technology use along a few characteristics such as compatibility, complexity and relative advantage, and to report how often each specific technology was used. All questions in this section used Likert scale questions with a scale of 1-4 with 1 indicating "not at all" and 4 indicating "very much/often".

Teacher survey.

Teacher surveys included 4 sections: Section 1was about teacher background information, including subjects taught, workload, time spent on computers, computer use, years of teaching, and grade taught. Questions in this section were multiple choice questions. Section 2 investigated teachers' attitudes and beliefs, including attitude toward using technology, beliefs in using technology and pedagogical beliefs. Statements on attitudes and beliefs about technology use were listed and teachers were asked to indicate the extent they agreed with each statement on a Likert-scale from 1 to 5 with 1 indicating "strongly disagree" and 5 indicating "strongly agree". Section 3, which was a set of problem-solving scenarios developed according to technology standards for teachers, evaluated teacher technology proficiency. Section 4 listed possible technology uses for teachers based on interviews and classroom observations, and asked teachers to rate each technology use on four characteristics: how often it was used, how difficult it was to use, how much change was needed to use it, and how beneficial it was.

Classroom observations

At two different points in time during the academic year, the researcher observed how teachers and students use technology (including the laptops) in different classroom settings. Data were collected through observations. Written consent was sought from teachers, students and their parents. The data obtained were from those teachers who gave written consent and those students who gave written consent along with their parents.

Interview

In-depth interviews were conducted twice over the academic year. Ten teachers and nine students were interviewed in the first interview, and six of the 10 teachers were interviewed again in the second interview. The interviews were designed to get inside stories on how the subjects used technology, for what purpose(s), what factors influenced their technology use, and how their uses had changed over time, etc. All participants were interviewed individually, and each interview lasted for 25-50 minutes. For data coding purposes, all interviews were audio-recorded. Written consent was sought from teachers, students and their parents.

In addition to individual interviews, group interviews were also conducted at four teacher team meetings, two at each time point.

Data Analysis

Data cleaning

Student data cleaning.

There were 237 students attending this middle school during the 2003-2004 academic year. 207 students finished pretest surveys, and 200 students returned valid (the number of missing values in returned surveys was smaller than one third of total items) posttest surveys. Among them, 177 students finished both pretest survey and section 1-5 of posttest survey. Data from students with section 6 (technology use) missing from their posttest surveys and those with more than one third of all responses missing were deleted (N=34), and data from special education students were also deleted (N=10) from dataset one. Therefore, 133 students' data were retained for final data analysis. Of the 133 students, 64 (48%) were male, 69 (52%) were female, 64 (48%) were 7th graders, and 69 (52%) were 8th graders.

Teacher data cleaning

28 teachers finished pretest teacher surveys. 20 of these returned valid posttest surveys while 8 teachers, who did not participate in the pretest surveys. Data from part-time teachers (N=2) and teachers who taught non-academic subjects such as PE, Music and Counseling (N =6) were deleted. Finally 20 teachers' data from both surveys were retained for final data analysis.

Reliability Check

Reliability was checked for research designed scales. The reliability of the student technology proficiency scale was 0.62 for pretest survey, 0.64 for posttest survey, and 0.69 for both pretest and posttest surveys. The reliability of the student technology use frequency scale was 0.92, for the technology use benefit scale was 0.95, and for the technology use difficulty scale was 0.95. The reliability of teacher technology use frequency, difficulty, change, and benefit was 0.76, 0.92, 0.79, and 0.85 respectively. Please see Table 3 for details.

Table 3: Reliability Check for Research Designed Scales

Scales	Subscales	Reliability
Student Technology Proficiency	Pretest	0.62
	Posttest	0.64
	Both Pre-post test	0.69
Student Attitude and Belief	Pretest	0.84
	Posttest	0.94
	Both Pre-post test	0.95
Student Technology Use	Frequency	0.92
	Difficulty	0.95
	Benefit	0.95
Teacher Technology Proficiency	Pre-test	0.35
	Post-test	0.34
Teacher Attitude and Belief	Pre-test	0.73
	Post-test	0.77
	Both Pre-post test	0.84
Teacher Technology Use	Frequency	0.76
	Difficulty	0.92
	Benefit	0.79
	Change	0.85

Data integrating

Based on study design and through Principal Component Analyses, the teacher data were reduced to the following variables: positive belief about technology, current technology use status, social/self aspect of technology use, time constraint as a barrier of technology use, computer anxiety, school rapport, negative attitude on technology use, computer interest, perceived technology support, traditional pedagogy, constructivist technology, social connectedness, time spent on technology, and technology use variety(see Appendix A for detailed information).

For each student, all teachers that he/she had taken courses from during 2003-2004 academic year were identified. Data of these teachers were pulled out for each student. For every teacher variable, a mean score was obtained by taking the average of the scores on this variable for all teachers this student had, and a variation score was obtained through calculating inter-quartile scores. The mean scores and variation scores on teacher variables were integrated with the data from each student. The final data set included data for each student on both pretest and posttest surveys and the aggregated data of the teachers each student had. Taking students as the key-stone species, all the teachers they had were viewed as environmental factors.

Data analyzing

According to several specific research questions, this study applied a number of data analysis methods. First, paired Sample T tests were conducted to identify changes in the users and environment. Correlation analysis were conducted to reveal the relationships between the Key-stone species and the environment, and Multivariate General Linear Model and Linear Regression analyses were employed to reveal the complex relationships between different species and the environment and how the relationships changed over time.

Second, qualitative data collected from interviews and classroom observations were coded according to specific research questions. Coded data were analyzed to describe and explain the process of co-evolution, such as how innovation decisions were made, how different users applied technologies to solve their problems, how different factors interacted with each other, how technology use was rejected or adopted, and how it interacted with existing species and the environment. Patterns were identified and specific cases and examples were derived from these data.

Third, for the final depiction of the nature and process of technology use in schools, a relationship model was constructed based on theories and previous research. Multivariate General Linear Model analyses were performed to identify possible statistically significant relationships, and on the basis of these, individual Linear Regression models were built to verify the final theoretical model.

CHAPTER 5

RESULTS AND DISCUSSIONS

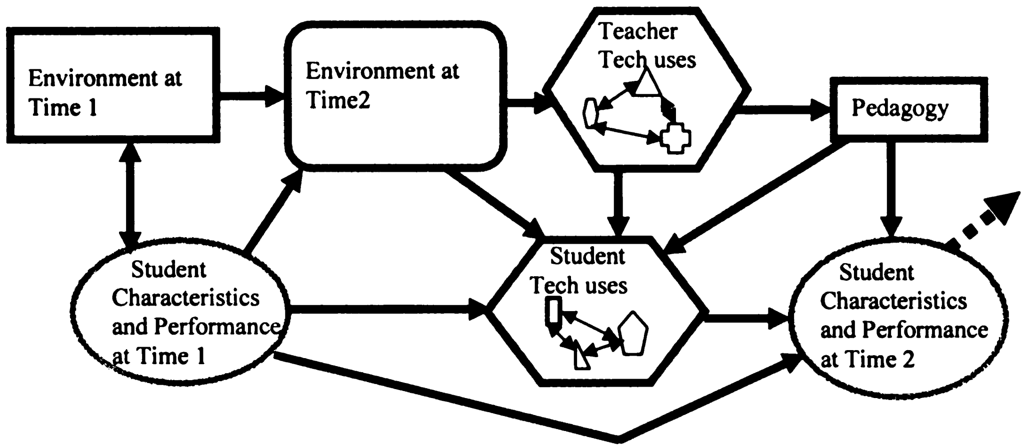
This chapter discusses the main results from data analyses that address three major research questions: a) What the dynamics of technology use in schools are, which will entail a holistic discussion of the nature and process of technology use. b) How different technology uses have changed over time; and c) What influences change in technology use;

5.1. The Big Picture: Co-Evolution—the Dynamics of Technology Use In Schools

Through examining technology use in schools from an ecological perspective, findings from this study reveal that what and how technology is used in schools is not decided by the users alone, neither is it decided by the specific technologies, or the school environment, but by the ongoing dynamic interactions among the users, technology uses and the school environment.

As shown in Figure 2, students and their environment have mutual influences on each other, the environment changes over time, and student characteristics influence changes in the environment; the environment factors influence how teachers use technology, which also affects the way teachers teach; student characteristics, environment factors, teacher technology use, and pedagogy influence how students use technology; students' technology use has some impact on their performance and developmental outcomes, which exert further influence on the environment. Therefore, the three major components are inter-dependent and interconnected, and they exert influence on each other. Any change can be felt throughout the whole system because of the strong interrelationships and dependencies in the ecosystem. The change in one component may cause changes in other components, which result in further changes in the whole system.

Figure 2: Co-evolution: The Dynamics of Technology Uses in Schools



In the following section, specific results related to the mutual influence and interconnections between the users, the environment, and technology uses will be presented to illustrate how the different species affect each other, co-evolve, adapt to and change the environment.

The interconnection and mutual influence between users and the environment

First, users and the environments have mutual influences on each other. On the one hand, users are not just passive recipients sculptured by their environment. On the contrary, they exert a certain influence on their environment. As Lewontin (2000) points out, the organisms not only decide what constructs their environment, but also are "in a constant process of altering their environment" (p.55). Moreover, "organisms alter not only their own environment but also the environments of other species in ways that may be essential to the life of those other organisms" (p.55). On the other hand, the environment also affects the activities and relationships of the species.

Table 4: Relationship between the organism and the environment at time 1
Correlations (Pearson correlation) (N = 130)

Environment variables Time 1 / Student variables Time 1	pressure of tech use	time constraint	tech anxiety	negative attitude on tech	Perceived tech support
Pretest GPA	.351(**)	-.224(*)	-.181(*)	-.096	.213(*)
Time spent on computers	.191(*)	.069	.038	.050	.189(*)
Learning Habits	.082	-.189(*)	-.181(*)	-.189(*)	.107
FITness	.292(**)	-.013	-.072	-.041	.321(**)

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

As shown in Table 4, students' characteristics are closely related to their environment. For example, students' learning habits represent an important factor that is significantly related to a number of environmental factors. Specifically, the better the student's learning habits, the less likely his teachers view time constraint as one barrier in using technology, the less computer anxiety his teachers feel, and the less negative attitude they have on technology. Higher student technology proficiency is related to higher pressure for using technology in the environment, and also related to higher perceived technology support. This is probably due to the fact that more technology proficient students not only help their teachers recognize the importance and possibility of using technology, but also actually provide technology support to their teachers in the classrooms.

The school environment changed overtime

The school ecosystem is a lively, human, and intensely social place, even if it incorporates very advanced technologies. It provides many different resources and materials and allows for individual proclivities and interests. As species in this ecosystem change over time, the ecosystem changes too. In addition, the social and technical aspects of an environment co-evolve. As a dynamic system, the school ecosystem evolves as things come and go, and relationships between species change overtime. Changes can occur in any dimension or in multiple dimensions. For example, with more and more technologies coming in, technology availability is gradually increased, and hence there are improved opportunities for teachers to interact with and use technologies. Other factors such as how peers use technologies and what expectations parents and students hold for the teachers in terms of technology use all have an impact on how a teacher uses technologies.

As shown in table 5, almost all environmental factors changed significantly over one academic year. Compared with the beginning of the year, teachers spent more time on computers at the end of the school year, their beliefs and attitudes significantly increased, while their perception of the availability of technology support decreased considerably. This may be due to the fact that with increased technology use, more technology support was needed, or that their expectations of adequate technology support were not met.

Table 5: Changes in the environment

	Mean difference	p	Variation Difference	p
Positive belief	.081	.004	-.066	.376
School rapport	.186	.000	.180	.001
Attitude on Laptop	.437	.000	-.032	.147
Attitude on tech use	.335	.000	-.168	.000
S/S Aspect of Tech Use	.345	.000	-.475	.000
Pressure on tech use	.2545	.000	-.231	.000
Time on tech use	.322	.000	.343	.000
Time constraint	-.299	.000	-.067	.214
Tech anxiety	-.276	.000	-.317	.000
Tech interest	-.004	.766	-.189	.000
Perceived Tech support	-.074	.012	.318	.000
Environment Having Many Innovation	-.031	.033	-.061	.006
Social connectedness	-.265	.000	-.092	.000

Teachers have changed greatly. The changes are visible to students. During the interview, one student said: "At the beginning of the year, because this is the first year the teachers have laptops, so at the beginning, they kind of don't know what to do with us. We asked: can we use out laptops? They said: "NO." because they didn't know what we could do on the computers. As opposed to taking notes on our computers, we could go on to the Internet, and it was hard for them to tell. But now they know when we are at the First Class." Another student also said: "The teachers have changed; they've grown to like it, the laptops. I think they are better with them (laptops) as they are using them more."

Parent involvement has significantly increased in the last year. At the beginning of the academic year, parents, in general, spent little time with children working on their homework or on computers. About half of the parents (46.3%) spent no time working with their children on their homework, and 78% of them never worked with their children on computers. At the end of the school year, parents spent significantly more time working with their children on their homework and on their computers. The percentage of parents who never spent any time working with their children on their homework or computers decreased to 31.6% and 54.2% respectively.

One direct benefit of these changes is timely and convenient communication between teachers, students and parents, which seems lead to more equal learning opportunities: "I can say that students and parents can not say that they are not aware of what's going on in the school, what's going on with their child. Students cant' say they don't know what's going on in their classes even if they are on a field trip. Everybody is on an equal ground in terms of information available. Set everybody on the same page in terms of the goals and objectives of the school."

Concerns related to technology use

However, "With great power, comes great responsibility". The laptop project has provided great opportunities and resources for teaching and learning, but also brought some new issues that teachers, students, and parents need to learn how to deal with.

As an innovation in its experimental stage, the laptop project has inevitably aroused some concerns, mainly from adults. For example, 39.3% of the teachers believed that it had become harder for their students to concentrate in class after having the laptops. They thought that students were being distracted by the Internet, e-mail, games, music, and so on. However, students were more optimistic about their ability to deal with laptop related problems. Most of the students (83.9%) did not agree that it was harder for them to listen to the teachers in class after having a laptop. Data from interviews also show that students were able to recognize the potential distractions attendant with having laptops, and they were learning to deal with these problems. Classroom observations reveal that the extent of students not concentrating in class varied greatly in different classes. Some teachers had good strategies to monitor students and kept students engaged in their tasks, while a few teachers were deeply concerned with this problem.

Another concern related to how to teach students to be more critical and not to take everything online for granted. Teachers worried that students might just copy and paste from the Internet, that they did not think critically, and took everything online as facts without careful scrutiny. Some teachers started thinking of ways they could help. For instance, one literacy teacher, through the Media Literacy Grant program, was teaching students to be more conscious consumers of the laptops and media, to learn how view things critically and scrutinize them.

Some of the concerns are actually attitudes and beliefs. Some people are more comfortable with traditional ways of teaching and learning and do not feel secure with innovations and changes. For instance, some parents preferred their children learn from books than computers, although no evidence showed that learning from books was better or more efficient than learning from computers. Similarly, some teachers worried about students' ability to read and write with paper and pencil. Like these parents, some teachers hoped students would still value traditional ways of learning through books, paper and pencil. Their feelings were mixed because, on the one hand, they knew students were going to be living in a digital era where paper and pencil might not be as important as in the past; on the other hand, they still wished students would have good penmanship and appreciate the value of books.

It might be helpful for teachers to discuss these issues and exchange their experiences and ideas, and also to discuss them with students and help them better discipline themselves in class.

What contributes to the environmental changes

The school ecosystem has changed significantly along almost all the dimensions evaluated. This section presents regression analysis results for two major dimensions of environmental factors: technology support and time constraint as a barrier in technology use.

What affects teacher perceived technology support at the end of the school year. This regression model is statistically significant ($P < .001$) and it explains 46.2% of the total variation.

Table 6: What affects teacher perceived technology support at the end of school year

Effect	Regression coefficient			t	p
	β	SE(β)	Effect size		
(Constant)	1.845	.426		4.326	.000
Teacher social connectedness T1	.398	.101	0.69	3.924	.000
Gender	-.024	.041	-0.10	-.58	.562
Grade	-.229	.046	-0.87	-4.96	.000
GPA	.112	.037	0.54	3.06	.003
Student FIT T1	.012	.008	0.25	1.43	.156
S Learning Habits T1	.021	.040	0.09	.52	.602

As shown in Table 6: student grade and GPA have some impact on teacher perceived technology support. Comparing with 8th grade, 7th grade teachers have more perceived technology support (ES= .87, $P < .001$). Students' higher GPA also helps improve teachers' perceived technology support (ES = .54, $P < .01$)

Table 6 also shows that how socially connected teachers are is a critical factor influencing their perception on technology support (ES = .69, $P < .001$). In this study, "social connectedness" means how much interaction a teacher has with her/his colleagues. The more socially connected a teacher is, the more technology support s/he can get. This finding confirms previous research arguments that teachers' social network affects the social capital they can get (Frank, Zhao, & Boreman, 2003), and more socially connected teachers have a better awareness on where and how to find help when needed.

Students influence the degree of teachers' viewing time constraint as one barrier in using technology, which greatly affects how much technology is used by teachers. This regression model is statistically significant ($P < .001$) and it explains 75.4% of the total variation.

Table 7 shows that students' grade level and their pretest technology proficiency influence their teachers' perception of time constraint as a barrier in using technology. Comparing with 7th graders, the teachers of 8th graders are significantly more likely to view time constraint as a barrier in using technology (ES = .98, $p < .001$). Student technology proficiency has positive impact on teachers' perception on time constraint (ES = .30, $p = .088$). This may because students with higher technology proficiency not only need less help on using technology to complete learning tasks, but also may help teachers solve technological problems in classrooms, thus help teachers save time in using technologies for teaching and learning purposes.

Table 7: What Affects Teachers' Perception Of Time Constraint As A Barrier

Effect	Regression coefficient			t	p
	β	SE(β)	Effect size		
(Constant)	3.952	.594		6.658	.000
Grade	.263	.047	0.98	5.54	.000
Student FIT T1	-.009	.005	-0.30	-1.72	.088
Attitude on Laptop T1	-.771	.166	-0.82	-4.65	.000
Tech. support T1	-.774	.161	-0.85	-4.80	.000
Social connectedness T1	-.333	.088	-0.67	-3.79	.000
Teacher FIT T1	.583	.066	1.56	8.84	.000

Table 8: Environment and Teacher Variables Affect Teacher Tech Use

Effect	Regression coefficient			t	p
$R^2 = .971$	β	SE(β)	Effect size		
(Constant)	-7.070	1.372		-5.151	.000
Tech support2	2.945	.078	6.68	37.95	.000
Attitude on tech use2	1.153	.169	1.20	6.80	.000
Tech interest2	4.127	.126	5.78	32.85	.000
Current tech use status	1.447	.091	2.81	15.96	.000
Social connectedness2	1.975	.118	2.95	16.77	.000
School rapport2	.567	.199	0.50	2.85	.005
Time constraint2	-1.643	.085	-3.39	-19.25	.000
T perceived S/S effect of tech use2	-4.242	.117	-6.39	-36.29	.000
Environment having many innovations2	-2.706	.274	-1.74	-9.89	.000

Teacher technology use is affected by the environmental factors at the end of the school year

This regression model is statistically significant ($P < .001$) and it explains 97.1% of the total variation.

As shown in Table 8: all the factors that influence teacher technology use can be categorized into two groups in terms of the directions of their impact: positive factors and negative factors. Among the positive factors, technology support has the biggest effect size ($ES = 6.68$, $P < .001$), which indicates that for teacher technology use, the availability of sufficient technology support is a serious concern. Data from interviews also reveal that the availability of technology support not only influences how much technology teachers use, but also affects which technologies they use. For example, the removal of Smart Board from classrooms was, to a great extent, due to the fact that it broke down easily and timely technical support was not sufficiently provided. Not surprisingly, teachers' attitudes toward technology use significantly influences their technology use ($ES = 1.20$, $P < .001$). Teachers' technology interest is another critical factor that has great impact on their technology use ($ES = 5.78$, $P < .001$). In addition, how socially connected the teachers are also significantly influence teachers' technology use ($ES = 2.95$, $P < .001$). This can be explained from a number of angles. First, more socially connected teachers can get more technology support from their colleagues, which significantly affects how much technology they use, as discussed in previous sections; second, more socially connected teachers have more channels to get information related to technology use, such as subject-related resources, tips on using specific technologies, and professional development opportunities and choices. This kind of information can help teachers perform better cost-benefit analyses and make well-informed decisions. Third, it is arguable that more socially connected teachers are under higher peer pressure related to technology use, especially in an environment where most people are trying hard to incorporate technology in their classrooms.

Factors that seem to have negative effects on teacher technology use, as shown in Table 8, are time constraint, perceived social/self effect of technology use, and an environment with many innovations. Time constraint has been identified as one barrier for teacher technology use in previous research (e.g. NCES, 2000). Results from this study show that teachers' perceived time constraint had a significantly negative impact on their technology use (ES = -3.39, $P < .001$). The social/self effect of technology use was measured by two statements: "The more technology you use, the more respect you will get from other teachers" and "The more technology you use, the more likely you'll get promoted." It is interesting to find that this factor was negatively related to teacher technology use (ES = -6.39, $P < .001$). Another factor that had negative impact on teacher technology use was the amount of innovations in the environment (ES = -1.74, $P < .001$). When too many innovations were introduced into this environment, it might have posed distractions to the users, thus making it difficult to make decisions and focus on innovations that best fit their needs. In addition, from the ecological perspective, as a species, a new technology use needs resources to develop, so too many innovations consume too many resources (time, energy, and technology support) which cause more tension on overall technology use.

Teacher technology use affects overall Pedagogy

Teachers' technology use and their pedagogical beliefs and practices have been controversial issues for some time. Generally it has been argued that teachers' pedagogical beliefs and practices determine what technology they use and how they use technology (e.g. Becker, 2001).

Results from this study reveal, however, that the relationship between teacher pedagogy and technology use is not one-way and uni-lateral, but two-way and bi-lateral. On the one hand, as previous research argued, teachers' pedagogical beliefs and practices do affect how they use technology. As discussed earlier in this chapter, it was generally accepted for teachers to use technology to support their current teaching practices, especially when these teaching practices were viewed as of high quality.

On the other hand, teachers' technology use also influenced their pedagogy. During the interviews, teachers talked about how the use of technology changed the way they teach. For example, B, a science teacher, believed he was teaching differently from the way his teachers taught him, and also differently from how he taught before using technology:

> *For the last a couple of days, we were doing moon faces, so they are going online and looking up the moon faces on a calendar, figuring out the moon cycle, so it totally changed the way you teach because you can let them discover things and then talk about it afterwards. When I was in school, teachers told you about it and then you did an experiment after you already knew about it. This way, they can find information and start formulating their own ideas and their own learning. I just come in the end, quote the pieces and make sure the pieces are fitting together.*

Interviews with students also reflected changes in teacher pedagogy. For instance, M, a 7th grade student, liked the Aleks program because "you can learn so much from the computer, more than the teacher standing in front of the classroom and explaining it. You can go on your own pace and nobody can hold you back. The teacher still stands in front of the room, but it's much less and it's about different things."

Quantitative data also revealed the impact of technology use on teacher pedagogy. This regression model is statistically significant ($P < .001$) and explains 53% of the total variation ($R^2 = .53$). As shown in Table 9, the variety of technology use has significantly positive impact on teacher pedagogy ($ES = 0.74$, $P < .001$). Specifically, the more diversely a teacher uses technology, the more constructivist her/his pedagogy is. However, the time spent on technology use is negatively related to constructivist pedagogy ($ES = -.97$, $P < .001$), which means the more time a teacher spends on technology use, the more likely that s/he adopts a more traditional pedagogy. A possible explanation is that if a teacher spends too much time using technology in class, the time and opportunities for students to use technology or to work on their own are limited.

This result has significant implications for future research and practices. In general, teachers are asked to use more technology — meaning spending more time on technology — in their classrooms, and at the same time are also asked to adopt a more constructivist pedagogy. This finding indicates that these two requirements might conflict with each other. If we want to have some influence on teacher pedagogy through the use of technology, instead of focusing on how much technology is being used, it probably will be more effective to encourage teachers to explore more diverse use of technology.

Table 9: Factors Influencing Pedagogy

Effect	Regression coefficient			t	p
$R^2 = .53$	β	SE(β)	Effect size		
(Constant)	5.25	.318		16.52	.000
Teacher time on tech use	-.514	.094	-0.97	-5.50	.000
Teacher Tech use variety	.093	.022	0.74	4.20	.000
Student Learning Habits T1	.001	.031	0.01	.04	.970
Student GPA T1	-.043	.028	-0.27	-1.56	.122
Student FIT T1	-.020	.006	-0.54	-3.05	.003

Pedagogy affects student technology use

Teachers' pedagogy influences students' overall technology use (ES = 0.44, P < .05). Specifically, the more constructivist the pedagogy is, the more technology students use. This is understandable in that teachers who adopt constructivist pedagogy allow students time to work on their own projects, and also encourage students to use technology.

Table 10: The Impact of Pedagogy on Student Overall Technology Use

Effect	Regression coefficient			t	p
	β	SE(β)	Effect size		
(Constant)	-4.630	1.844		-2.511	.014
Pedagogy	1.270	.505	0.44	2.515	.014

This model is statistically significant ($P < .05$), but it only explains 6% of the variation ($R^2 = .06$), which means that teacher pedagogy explains 6% of the variance in student technology use. Further analyses were conducted to explore other factors that affect student technology use. Student technology uses were categorized into five types: general technology use, subject-specific technology use, social-communication technology use, construction technology use, and entertainment-exploration technology use (Please see Appendix B for the categorization of these five types of technology use). This categorization was based on Levin and Bruce (1997)'s terms for technology use, but was modified to fit the diverse technology uses in this study. The following table presents the factors that influence each type of student technology use. Results were derived from regression data analyses. Factors that have significant or borderline significant impact on technology use, along with the effect sizes, were listed in this table. For detailed results on each technology use, please see Appendix C.

Table 11: Factors Influencing Student Technology Uses (Effect Size)

Student Tech Use	Student Characteristics	Environment	Teacher Technology Use	Pedagogy
General Tech Use	Pretest GPA .43*	Social Connect .27		T. Pedagogy .30
Subject-Specific Tech Use	Parental Involvement .40*	Time Constraint. -.56**	T FIT .49 **	T. Pedagogy -.29
	Student Tech Interest -.26	Tech Interest .69**	General tech use -.64**	C. pedagogy .32
		Tech support .58**		
Social-Communication Tech Use		Tech support .44*	Variation of time on technology -.32	
		Tech Interest . 50**		
		V. Tech Interest -.32*		
		V. FIT -.25		
Construction Tech Use		Social Connected .59**	Variety .49**	v. pedagogy -.49**
		Many innovations .50**	Time on tech -.54**	
Entertainment-Exploration Tech Use		Tech Interest .37*		T. Pedagogy .29
		Attitude with laptop .28		V.C. Pedagogy .34
		Tech use status .43*		
		Tech support .27		

Note: * 0.01< p < .05 ** p < .01

First, the environment factors significantly influence how students use technology in schools.

Technology interest of the teachers was evidently the most prominent influence on student technology use. It significantly affected student subject-specific technology use (ES = 0.69, $p < .01$), Social-Communication Technology use (ES = 0.50, $P < .01$), and Entertainment-exploration technology use (ES = 0.37, $P < .05$). Presumably, if teachers had high technology interest, they were more encouraging and supportive to their students in using computer technology.

In addition, the consistency of technology interest in the environment also has an influence on student technology use, specifically on social-communication technology use. The bigger the variation in technology interest, the less likely students used technology for social and communication purposes (ES = -.32, $P < .05$). Large variation in technology interest meant big differences in technology interest among different teachers. Many not only had different attitudes toward students using technology, but also differed in their responses to their students' messages (such as how quickly they responded to student e-mails and how helpful they were with e-mail messages versus face-to-face communication). These differences might present a measure of confusion and uncertainty for students attempting to use technology to communicate with their teachers, and thus reduced the likelihood of them using social-communication technologies.

Technology support was another factor that significantly affected student technology use. The more sufficient technology support was perceived to be, the higher uses of subject-specific technologies (ES = 0.58, $P < .01$), and Social-communication technologies (ES = .44, $P < .05$).

Second, in examining the impact of teacher technology use and ability on student technology use, Teachers' technology proficiency was a positive predictor of subject-specific technology use (ES = 0.49, P < .01), and the variety of teacher technology use facilitated student construction technology use (ES = 0.49, P < .01). The more time teachers spent on technology in the classroom, the less likely students used technology for construction (ES = -.54, P < .01).

The impact of technology uses on student outcomes

Student outcomes focused on four aspects: GPA, FITness (Technology proficiency), Learning habits, and Developmental outcomes (self-esteem, attitude towards school, and life skills). The following table summarizes the impact of five types of technology uses on these four student outcomes:

Table 12: Impact Of Student Technology Uses On Student Outcomes

Student Outcomes / Student Tech Uses	GPA	FITness	Learning Habits	Developmental Outcomes
General tech use	0.10	**0.32**	0.11	-0.03
Subject-Specific tech use	0.04	**-0.43***	0.04	-0.03
Social-Communication tech use	0.21	-0.10	-0.09	**0.35***
Construction tech use	0.00	-0.21	-0.16	0.00
Entertainment/Exploration tech use	-0.24	0.13	**0.51****	-0.08

* 0.01 < P < 0.05
** P < 0.01

Results in Table 12 show that different technology uses have different impact on specific student outcomes. General technology use has the biggest impact on student technology proficiency (ES = 0.32, P = .07), while subject-specific technology use seemed to have a negative influence on student technology proficiency (ES = -0.43, P < .05). This is understandable in that when using more general technologies, the tasks are not certain and students have more opportunities to explore new features of certain technologies, and thus have the opportunity to learn more about technology; while when they use subject-specific technologies to learn, the tasks are focused on specific subject content, and the procedures to accomplish the tasks are generally similar, so once students know how to follow these procedures, there are no technological challenges, and thus no opportunities to learn new technology knowledge and skills.

Using technology for social-communication purposes has some positive impact on student GPA. Although this impact is not statistically significant, an effect size of 0.21 on GPA is considerably large comparing with a possible 0.33-0.50 effect size gain on student performance based on "everything that happens to a student" (Kane, 2004) across one academic year. This impact is due to the fact that students use social-communication technologies to communicate with teachers about school work such as assignments and questions, and they can get response more quickly than with traditional methods. Social-communication technologies also provided students more opportunities and avenues to ask questions. For example, one teacher mentioned that he received e-mail messages from students who were too shy to ask questions in the classroom. This was also reflected in student interviews. All students mentioned that it was easier and more convenient to ask questions or set appointments with teachers through e-mail. One student said she "talk to them (teachers) a lot more. If you have a question, even if you are at home, you can e-mail them and ask them. You don't have to wait til class to ask. By then you may have already forgot. I can get a response pretty quick." Another student also said that it was easier to e-mail teachers to ask questions because "we don't have to go and find that specific person."

Social-communication technology use also had a significantly positive impact on student developmental outcomes (ES = 0.35, $p < .05$). It is arguable that the more students use technology for social-communication purposes, the more they feel socially connected, which is very important for teenage students who need support from their peers and adults.

Entertainment-exploration technology use significantly influenced student learning habits (ES = 0.51, $P < .01$), but had a negative impact on student GPA (ES = -0.24, $p > .05$). It is likely that spending time on entertainment and exploring with technology helps students to better organize their learning tasks; for example, remembering and following rules in computer games may help students better follow instructions in classrooms, which is supposed to be beneficial to student learning outcomes. However, it seems this potential advantage was nullified or even outweighed by the consequences of spending too much time on entertainment-exploration technology use.

In terms of the impact of technology use on student academic achievement, none of these technology uses had a significant effect on student GPA. This result suggests that we should be realistic about the impact of technology use on student outcomes.

This might be disappointing to some people in that a major argument and goal for integrating technology in schools has been to improve student achievement.

However, first, although student technology uses were divided into five types of technology uses, the five types are still too general to be able to differentiate the effects of different specific technology uses. If the specific technology uses within the same type had a different impact on student outcomes, their impacts might have cancelled out each other.

Second, student academic achievement was measured by traditional methods of assessment, which is very likely not an accurate assessment of student learning with and about technology. As a teacher pointed out during the interview, student learning with technology is difficult to measure because much of this kind of learning is hidden. Students have the opportunity and resources to extend much more than what they do in classrooms, so "I don't think we have a way to evaluate it yet, or we don't ask the right questions to find out what they did."

5.2 How different technology uses have changed over time – the evolution of technology use

Analyses of interview data reveal that, as in natural ecosystems, species in the school ecosystem evolve over time. Through interactions with the users, the context, other technology uses, and existing practices, different technology uses took different evolution paths. Specifically, seven different evolution paths were identified: Always thriving in the whole ecosystem (Path 1), Always thriving in a few habitats (Path 2), Growing (Path 3), Were thriving but now dying (Path 4), Were flourishing, now dead in most places but still thriving in a few habitats (Path 5), Introduced in but never survived (Path 6), and Marginal existence (Path 7). Table 13 lists technology uses for each evolution path.

Table 13: Evolution Paths and Technology Uses for Each Path

Evolution path	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6	Path 7
Tech use	Internet Word E-mail	TI calculator Excel	PowerPoint Aspire Aleks Stickies	Grade Machine Telephone	Overhead Projector TV/VCR	Smart Board	Photoshop Imovie

Note: To save space, technologies (e.g. "Internet" and "Word") are listed instead of specific technology uses (e.g. "using Internet to search for information" and "using Word for writing").

The following section discusses the different evolutions paths, representing technology uses for each evolution path, and the characteristics of technology uses for each evolution path.

Path 1: Always thriving in the whole ecosystem.

Some technology uses were popular in the whole ecosystem throughout the research period, similar to dominants in natural ecosystems. Some examples were: Internet, E-mail, and Microsoft Word. The main reasons for this invariable success were: a) They were in great need (niche); b) They did not consume too many resources: they were easy to learn, easy to use, and very reliable — seldom cause trouble; and c) They all had great adaptability: can be used by any one in any classroom and for any subject.

Path 2: Always thriving in a few habitats.

Some technology uses may not be popular in most of the ecosystem, but were being used a lot in a few habitats. TI calculator in math classrooms and Excel in science classrooms were two such examples. The main reasons for these technology uses' popularity in a few habitats were: a) the special niche they occupied in these habitats; b) teachers were highly proficient in using them; and c) they had easy accessibility.

Path 3: Growing.

Some technologies were not used much at the beginning of the academic year, but as time passed, their uses grew, such as Aspire, Aleks, Movie clips, and Stickies. Major reasons were: a) Perceived advantages of using these technologies attract more people to use them. b) Pressure from the environment (e.g., from peers, parents) forces more people to use them. c) Users were getting better at using these technologies. A detailed example on Aspire will be presented in the next section of this chapter.

Path 4: Were thriving but now dying.

Some technology uses were gradually being replaced by newer technology uses. For instance, telephoning teachers, a technology use very popular in previous years in this school, was greatly reduced this year because of the use of e-mail and the Internet for communication and information sharing. Similarly, a grade machine was being replaced by Aspire. Compared to their counterparts, these new species were more convenient to use and more compatible with a high-tech environment. In addition, if two technology uses had exactly the same functions and consumed the same amount of resources, then it was generally the case that the newer technology would replace the older one because of its symbolic meanings.

Path 5: Were flourishing, now dead in most places but still thriving in a few habitats.

Some technology uses were very popular at the beginning of the school year, but were replaced by other technology uses in most of the classrooms, yet still thrived in a few classrooms. One example was the overhead projector. The overhead projector was one of the most popular technologies at the beginning of the academic year. With the introduction of laptops, every classroom was equipped with a data projector, and a few professional development sessions on PowerPoint were provided to teachers. Consequently, the use of PowerPoint for content presentation replaced the overhead projector in most classrooms. The overhead projector was taken out of these classrooms. However, it still thrived in math classrooms because these teachers preferred to use the overhead projector for sketching and demonstrating how to solve a problem. Another example was the use of the TV/VCR to play videos. This school had access to video clips in UnitedStreaming, so most teachers used laptops to play clips from this resource, but the special education teacher still used the TV/VCR because it provided captions, which her students needed. The reason for these technology uses to thrive in a few special habitats was mainly because of the unique niche they occupied.

Path 6: Introduced in but never survived.

A new technology may not be adopted by the ecosystem and thus will be rejected. One example was the Smart board. When the Smart Board was introduced to the school, teachers were excited about it because its functions looked very impressive and it seemed to be very convenient. For example, the teacher could sketch on the white board and the computer could record the sketching, so the teacher could e-mail the revised file to her students. However, after a few trials, teachers were frustrated because there were too many technical problems. It was very time-consuming to set up and seldom worked. In addition, the niche it served —presenting materials — had been occupied: the white board and data projector serve almost the same purpose but work far more easily and stably. So the Smart Board was removed from this building.

Path 7: Marginal existed.

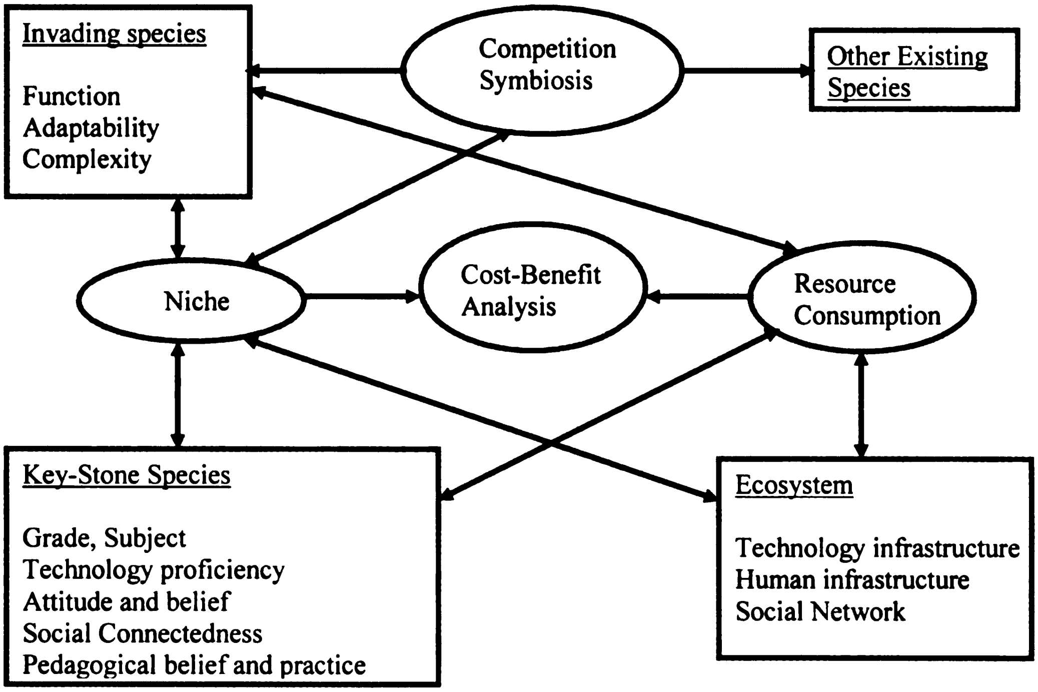
Some technology uses existed in this ecosystem, but only to a minimal extent. A few examples were Iphoto, Photoshop, Digital camera, Imovie, etc. The main reason for their marginal existence was that there was not much need for these uses, in other words, these species didn't find enough niches in this ecosystem. Teachers and students may explore some of these technology uses on their own, but did not use them for any real tasks.

5.3 Conditions for the evolution of technology uses

As discussed in the previous section, technology uses in schools change over time. It is a complex ongoing process influenced by its characteristics and the interactions with other species and the environment. This section discusses why different technology uses took different evolutionary paths and what factors influence the process.

Factors that influence the evolution of technology use and their sources are listed in Figure 3.

Figure 3: Factors and Interactions Influencing Technology Use



As shown in Figure 3, factors influence technology use at different levels. First, there are factors related to the specific technology use, the key-stone species, and the environment that affect how the invading species change over time; second, the interactions between these factors have critical influence on the evolution path of a technology use; and third, the interactions between these factors affect the role each factor plays, and thus exert further influence on technology use evolution. Consequently, the evolution of technology use is not only influenced by factors related to the specific technology use, the users, and the environment, but also affected by the complex interactions between these components. The following section will first discuss the factors related to the technology use, the users, and the environment that influence technology use evolution, and how these factors are influenced by each other. Subsequently, there will be discussion of the interactions between these components.

The factors influencing technology use in schools

Factors mainly related to the invading species

Whether an invading species survives or perishes in an ecosystem to a great extent depends on those of its characteristics that influence how it interacts with the environment. Findings from this study suggest that the following aspects of an invading species are crucial to its survival:

Technological function: Any specific technology has its own built-in functions. These functions represent the developer's knowledge of the connection between a problem and a solution (Zhao, Frank, 2003). These functions can be very specific and fixed; for example, the major function of an e-mail software is to send and receive e-mails. The functions can also be very general and flexible, such as the Microsoft

Word program, which has many functions and can be used in many different ways. Therefore, these functions determine what a technology can do and how it can be used, and therefore, to a great degree, determine the niche of a technology. However, this is not the only factor that determines the niche. Other factors also play an important role in shaping the niche. These factors will be discussed in the following text.

Adaptability. Adaptability means how flexible a species is. Like species in natural ecosystems, technology uses differ in terms of how well they can adapt to different environments or specific habitats. Technology uses that can occupy more than one niche, and serve different purposes in different setting are more likely to survive. For instance, the popularity of PowerPoint use in this school ecosystem is partly due to its high adaptability: PowerPoint can be used for different subject areas, by teachers or students, and can serve different purposes such as presentation, quiz, game, and student construction.

Adaptability of technology uses is also affected by the environment and the users. If the environment has sufficient technology support, then a technology use might find a bigger niche or be able to thrive in more habitats. Similarly, the users also make a difference in the adaptability of technology uses. Users with higher technology proficiency can use a technology more creatively, thus enhancing its adaptability. For example, e-mail is being used for communication by all teachers and students in the school ecosystem, while more technology proficient people also use it for file transferring or collaborative works, thus increasing the adaptability of this technology use.

Complexity. Complexity is the level of difficulty of a technology use. Technologies vary greatly in terms of their complexity, and this complexity affects how well a technology use survives in the school ecosystem.

Complexity is relative to the environment and the user's technology proficiency and experiences. An easy technology use may be viewed as complex when the environment lacks necessary support, or the user lacks necessary knowledge and skills. On the contrary, a complex technology use can also be viewed as easy when everything works together. For example, using a TI calculator for calculation and graphics is comparatively complex. However, in one math classroom, the teacher was very proficient and experienced with TI calculators, and students, fascinated by the functions of the TI calculators, were eager to learn and use them, every student had a TI calculator, and the content taught in one semester was very suitable for using TI calculators. Therefore, the complexity of this technology use was greatly reduced and its popularity increased.

Some technology uses are by nature more complex than others. However, the complexity can be reduced through providing more technology support or technology training. The specific technology can also be redesigned to make it more user-friendly.

Factors mainly related to the key-stone species

Subject. The subject not only influences how students and teachers use different subject-specific technologies, but also affects how they use general technologies such as the Aspire program. First, teachers and students in different classrooms may use different subject-specific technologies, such as Aleks, Geometer's Sketchpad, TI Calculator, and Carnegie Algebra Cognitive Tutor in math classrooms, and Desktop Publishing in language arts classrooms. In different subject areas, teachers and students also use general technology differently. For example, the Microsoft Word program was used for composing essays in language arts classrooms, and for Webquests in social studies classrooms.

Students. Students can be an important factor influencing teachers' decisions on whether, what and how technologies are used. For example, for the same subject, math, 7th grade classrooms used Aleks, while 8th grade classrooms used Carnegie Algebra Cognitive Tutor and Geometer's Sketch Pad. Students also make a difference in how different technologies are used. For example, the math teacher in the lower grade used ALEXK, but the math teacher in a more advanced class use two more complicated programs.

Moreover, student technology use and technology interest sometimes exerts pressure on teachers so that teachers have to change the way they teach and organize classroom activities to accommodate students' interests and needs. During the interviews, one teacher made these comments:

> *Students have grown up in the technological age, so they are used to computers, they are really comfortable with computers. Every time they work on computers, you see their interest level goes up, as opposed if I just have to stand there and tell them everything. Normal lecture is not exciting for them. They are used to video games, they like that constant glow off computers. When we do activities like that, I think they have changed, really engaged students.*

Class size. Some technologies may work better with a bigger class size, while other technologies may work better with a smaller class size. An example is the Aspire program. The program Aspire was used by almost all the teachers, but the special education teacher did not use it as much because she had a very small group (4) of students. Her students, although in the same class, were at different levels. So she had to assign different homework to each of them. Aspire did not save any work for her. The only thing she liked about Aspire was that the parents could check their students' grades conveniently.

Technology proficiency. Technology proficiency makes a difference among different people, also within the same person at different times. People with different technology proficiency levels use technologies differently. Generally speaking, people with higher technology proficiency use a bigger variety of technologies, use technologies in a more creative way, and encourage students to use technologies more.

Technology proficiency of both teachers and students increased over the year. This school provided many professional development programs for teachers. The school had a collaboration program with a local university. Through this program the teachers could take professional development courses within this school but received college credits or graduate credits. The courses were sometimes taught by a teacher from this school, and the content was focused on the specific technology programs used in this school, such as the Aspire program, PowerPoint, and Imovie. These programs were very convenient and helpful to teachers, especially those teachers who were not very comfortable with technology.

Pedagogical practice and belief. Teachers with different pedagogical practices and beliefs use technologies differently, and they all use technologies to support their pedagogies. For example, when talking about how technology use in this school facilitated teaching and learning, the principal gave a very good example involving two social studies teachers in this school who had very different approaches to teaching. One used a more traditional approach, while the other was more constructivist and problem-based; each used technology very differently:

> *We have excellent social study teachers: Dave and Gary. They are probably on the opposite ends of the spectrum for how they teach. They were*

that way before the laptops, and they are that way now. You can go into Dave's room. Kids are in straight rows, he teaches more structured things, they are having debates, he uses it for the quizzes, for the lesson plans, kids are taking notes on their laptops, he shows movies on the laptops, having American history discussions...you go into the next room, and Gary is doing small groups, the desks are all over the place, the kids are all over the place, they are making posters, they are designing webpages, they are doing projects...I think both teachers are being able to maintain teaching the way they want to teach and they are using technology as a tool. It doesn't drive the curriculum, it doesn't drive how they teach, they are able to still continue to do things the way they are comfortable doing it, the way they feel that needs to be done. They do use it very different ways, but use it successfully in their areas and it hasn't changed the quality of their instruction.

In this case, technology use facilitated teachers' existing teaching practices and pedagogy, and technology use was not even expected to change teaching practices. However, it should be clarified that the principal was very satisfied with the quality of both teachers' teaching. Therefore, changing pedagogy seemed to be unnecessary.

Social Connectedness. The school ecosystem is a lively, human, and intensely social place. As the key stone species in this social environment, the users are related to each other, and they have a mutual influence on each other's decisions about what and how technology is used. As a student said during his interview: "Everyone influences each other, because everyone has his own way." Similarly, another student commented: "Sometimes we learn from our teachers, sometimes from friends. We tell each other what we've learned and found out. That's how we learn." When talking about how she learned the Photoshop program, Alison, an 8^{th} grader, said: "It's really kind of like "monkey see, monkey do". My good friend was working on her picture on Photoshop, and I said wow, can you show me how you do that?"

Social connectedness not only influences how users learn a new technology, but also affects how they use technology by providing related information and exerting pressure to use the technology. Pressure for technology uses can come from different sources such as parents, peers, students, the principal, and so on.

Factors mainly related to the ecosystem environment

Factors related to environment that influence how technology uses evolve are:

Technology infrastructures. Technology infrastructure is the technology hardware facilities, software, and technology support available to teachers and students. This school had rich technology infrastructure. Besides one-on-one laptops, every classroom was equipped with a computer projector, screen, TV/VCR, an overhead projector, a data projector and some other stand-alone technologies, and the whole school had wireless access to the network. However, access was sometimes still a problem. For example, the science probes were described by some students as "very cool" during the interviews, and the science teachers also reported that students were very interested in and excited about using science probes. However, the fact that the whole school only had one set of science probes because of the high cost greatly limited its usage. This reveals a problem that many schools may face. On the one hand, there is not sufficient access to technology that students and teachers want to use; on the other hand, some technology facilities, such as the SmartBoard, are available but no one uses them. This suggests that when making decisions on what technology to purchase, more attention needs to be paid to the needs of teachers and students based on their current technology use.

Human infrastructure. This school provides good human infrastructure in the following major areas: a) Strong leadership. The principal had a strong vision about technology use in this school. He set the tone, communicated the school vision with staff, teachers and students, and enlisted their support. In addition, he gave teachers freedom, which helped them work together. He also recognized good practices of technology use and strongly advocated for these good practices. As mentioned by the teachers during interviews: "He has created an environment that works out for everybody." b) The environment was supportive and the atmosphere was friendly. People were encouraged to try new technology and new teaching practices. Teachers had many opportunities to try their own ideas, or to work collaborately and learn from each other. c). Convenient, effective, and sufficient professional development opportunities. This school (school district) provided teachers with plenty of professional development opportunities, strongly encouraged teachers to learn, and was able to "make it very easy for teachers to take technology classes that help". d). Timely technical support. The technical support staff was highly praised by the teachers and students during interviews. They worked diligently to help teachers integrate technology into classrooms, solved technical problems, learned about and introduced new technology, and provided resourses for teaching and learning.

Objectively, the ecosystem has one environment at a certain time point, but to every species or every organism in this ecosystem, the specific environment is different to each individual. For example, more socially connected people may get technical help from their friends in addition to school technology specialists. For instance, when asked where she could get help when something did not work, Julie, an 8^{th} grade students said that she got help from her friends: "My friends, I think they know more about it than I do, so when I don't know how to do things, they usually help me out. " Therefore, the environment has more technology support for a more socially connected person than some one who is less socially connected.

The interactions

Niche. Niche is the role a species plays in the ecosystem. The more important the role is, the more likely a species will survive. All popular technology uses serve universally important purposes in this school ecosystem, such as e-mail for communication and PowerPoint for presentation. In this sense, niche is decided by the specific technology uses, because technologies are designed to have certain functions and their uses are consequently defined by their capabilities.

The niche of a technology use is the results of the interactions between the technology use and the environment, and the interactions between the technology use and the users. First, the environment influences whether or not the niche of a technology use can be realized. A technology use may survive well if it serves a unique niche, such as using an overhead projector for sketching in math classrooms. On the contrary, if the environment does not have a niche and the technology use can not create one, then it can not survive. For instance, using Adobe Photoshop for digital editing was taught to students, and students also spent some time exploring it; however, it could not survive in this ecosystem because, as a student explained during the interview: "we really don't have any classes we can use it for. Also, you need a digital camera to use it. I don't have one. I can't use it anyway." In this case, the current practice and the limited resources in the ecosystem constrained this technology use.

Second, the characteristics of the key-stone-species, the users, affect whether or not a niche is identified for a technology use, and what specific niche a technology use can occupy in the school ecosystem. Even if users are very familiar and comfortable with using a specific technology, they still do not use it if there is no niche for this technology in their daily practices. For example, a social studies teacher mentioned that he did not use Excel although he knew this program very well, because "I don't need it in a 7th grade social science class." Different species migrate and change to fill various niches. Moreover, their niches also change according to the dynamic interactions among species and the system.

Resources consumption. Like their natural counterparts, technology use consumes resources. Resources in a school ecosystem can be money, technical support, time, and energy. The more complex, more difficult to learn, and more unreliable a technology use is, the more resources it consumes, and thus the less probability of its survival.

Resource consumption is the result of interactions between the technology use and the environment, and this result is mediated by the users' perception. The same technology may be viewed very differently in terms of resource consumption (more elaboration).

Competition and Symbiosis-Interactions between the invading species and existing species. The nature of interactions between species can be either competition or symbiosis. Competition happens when two species compete for the same niche or resources. For example, the overhead projector and PowerPoint compete for the same niche: presenting materials. Another example is the use of the Internet for information and getting information from the library. Symbiosis occurs when two species support each other. In classrooms, the use of the Internet makes PowerPoint presentations more interactive, dynamic and interesting. The use of one increases the use of another. So the nature of their mutual influence is symbiotic. Similarly, the use of Word to compose and using e-mail to communicate also support each other. In fact, in this school, using Microsoft Word for composing various writing tasks, using the Internet to search for information, and e-mailing friends were three of the most favorite technology uses. Sometimes these three types of technology uses were combined. For example, one popular learning activity in this school was Webquest. The teacher would e-mail students a work sheet in Word format, which asked students to search for information online and answer questions on the work sheet. When working on a Webquest task, students generally had two windows open at the same time, one for Microsoft Word and one for Internet Explorer, searching for information in one window and filling in answers in another window. After they finished answering the questions, they would e-mail their complete work sheet to the teacher.

In an ecosystem, different species migrate and change to fill various niches. Moreover, their niches also change according to the dynamic interactions among species and the system. For example, the invasion of technology has dramatically changed the niche of the library and the librarian.

> "*Maggie's job has changed probably the most, at least twice since she's been here. When she first started, she was in the library where kids checked out books, then the library became the place where we had the computers, we had the computer lab in the library that was open all the time. Students and teachers came to check their e-mails, do research,...and now with everybody having a laptop, kids don't have to go there for computers any more. With kids having all these resources, they don't have to use books for research as much. Everyday Maggie is redefining her position as a media center librarian and*

determining what her job is going to be what role the media center is going to be in a laptop school. There is no handbook to tell her how to do that. I think she is developing new ideas every week on how we can help support teachers and the kids."

Cost-benefit analysis. Whether or not a user adopts a technology use depends to a great extent, if not totally, on the analysis of how much cost has to be put in and how much benefit this technology use can bring. Cost-benefit analysis not only decides what technology innovations to be introduced at the ecosystem level, but also determines what and how technology is used at the individual level.

First, cost-benefit analysis plays a crucial role in the decision-making process regarding what specific technology will be introduced in the school ecosystem. At a teacher team meeting, the principal discussed the choices of class management systems. It was a good example that clearly illustrates how different factors were taken into account for a cost-benefit analysis in deciding what program to use for class management for the next academic year. There were three options under consideration. Each of the options had advantages and disadvantages, which affected how much resource needed to be invested (Cost) and how much the school could get out of it (Benefit):

Aspire: the advantages of the Aspire program were that it was already being used in this school, it was working well, and teachers and parents had already been trained for using it. The disadvantage was that they had to pay for using this program.

E-system: The advantages of the E-system were that it worked the same as Aspire; the school was already using some of its programs and paying some money for it. However, the disadvantages were that this program lacked the parent module, and the school might need to pay some extra money to implement it.

Apple Mac Schools: The Apple Mac Schools system had "everything from report cards, degrees, communicating with students and parents, posting grades," and "it also has administering stuff like scheduling, putting kids' proficiency scores, basically their permanent records will be available through that." Although they would also need to pay for using this program, if they chose this program, they could reduce the cost of a few other programs. The major drawback was that they had to train teachers, students, and parents for using this program, which they really did not wish to do.

There were advantages and disadvantages for each choice. Based on species characteristics, the data for cost-benefit analysis are listed in the following table 14:

Table 14: Cost-Benefit Analysis of Three Invading Species

Dimension / Technology	Current availability	Function	Training	Cost	Cost-Benefit Analysis
Aspire	+	+	+	-	++
E-system	+	-	+	-	0
Apple Mac Schools	0	++	-	0	+

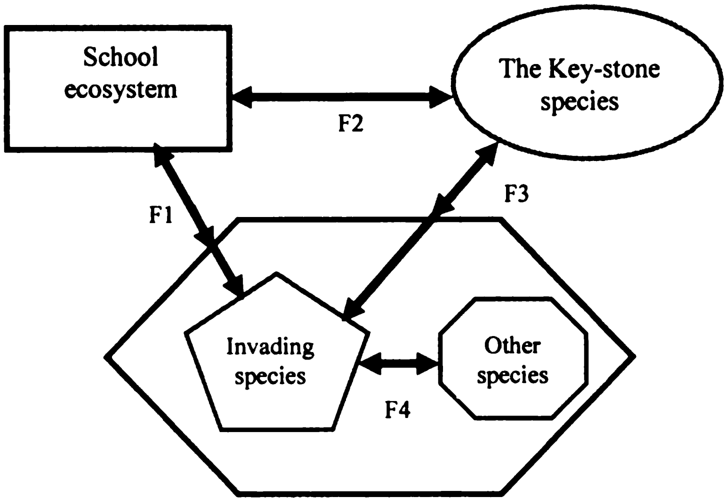
According to the principal, the criterion for the final decision was to "Think about what works the most effectively and what costs the least". The cost-benefit analysis, as shown in Table 14, clearly favors the Aspire program. It was not surprising, therefore, that ultimately the Aspire program was retained and no new program was introduced.

Second, cost-benefit analysis fundamentally determines what and how technology is used at individual level. A common thread across all interviews is to lower the cost of using technology and to maximize the benefits. For example, when taking about a program called FileMaker Pro, a teacher complained that it was somewhat troublesome to learn something different about this program every year, but "but for the most part, it's better than hand-writing for 10 pages" , so she still used it. Similarly, another teacher was suspicious of using Aspire program because "It was time-consuming to set up the student roster, set up the classes, putting in the assignments and grades, that's time-consuming." But he soon realized that "Once you have everything in place, it actually take much less time to do the work."

Summary

This section discusses the factors that influence technology use evolution in a school ecosystem. These factors are not independent of one another, and their impact on technology use evolution is not a simple and linear one. On the contrary, they are entangled with each other, and their influence varies from case to case. As shown in Figure 4, if F1 (Force 1) represents the interactions between the invading species and the school ecosystem, F2 (Force 2) represents the interactions between the key-stone species and the school ecosystem, F3 (Force 3) represents the interactions between the key-stone species and the technology use species, and F4 (Force 4) represents the interactions between the invading species and the school ecosystem, then the evolution of the invading species is not determined by any single specific factor or force, but by the combination of all the forces. In the following section, three specific cases will be presented to illustrate how technology uses evolve under the influence of the ongoing dynamic interactions between the ecosystem, the key-stone species, and technology use species.

Figure 4: What Influences Technology Use Evolution?



5.4. How Technology Uses Evolve: Cases

By comparing and contrasting technology uses taking different evolution paths, the following examples illustrate the complex process of technology use evolution, and how this process is shaped by continuous interactions between the components of the school ecosystem.

Case 1: PowerPoint and Overhead projector—growing versus dying

PowerPoint and the overhead projector are similar in a few ways: they both serve the same major niche in the school ecosystem: presenting materials. They both have great adaptability: they can be used by different users in different classrooms for particular subjects. They both are easily accessible in this ecosystem because every classroom is equipped with an overhead projector and a data projector.

They are also different in a few aspects: First, PowerPoint is more dynamic in that it is interactive and it can incorporate multimedia, while the overhead projector is plainer; Second, they consume different resources: using an overhead projector requires a copy machine, printer, transparencies, markers, etc, while using PowerPoint requires users to put more time and energy into learning and using it. Third, the overhead projector had been around for along time and was established in this ecosystem; while PowerPoint was a new technology and was an invading species.

At the beginning of the year, using the overhead projector for presentation was ubiquitous. Everybody knew how to use it and used it every day. It was especially convenient for some teachers who had accumulated many transparencies after teaching the same subject at the same grade for some years. They didn't need to make many new slides for their lessons. At first, then, the use of PowerPoint was mainly limited to a few teachers with high technology proficiency and those who were innovative at using technologies. Most teachers did not know how to use PowerPoint and were happy with the overhead projector. For them, the benefit of using PowerPoint was not enough to justify the time and energy they had to invest in order to use it.

As time passed, the use of PowerPoint steadily grew due to a few reasons: First, the increasingly technology-rich environment expected teachers to use more of PowerPoint because PowerPoint is a newer technology, and research shows that people generally favor newer technologies than older technologies (Zhao, Lei, & Conway, 2004). Second, there was pressure from the school district, students and peers that made teachers want to keep up with their peers who had already been using PowerPoint. Third, the school district had provided some professional development sessions on how to use PowerPoint, which not only greatly increased teachers' proficiency with PowerPoint and decreased their fear and doubt about it, but also provided opportunities for them to interact with PowerPoint. Fourth, the more familiar the teachers were with PowerPoint, the less time and energy they put into preparing a lesson with PowerPoint, which meant less resources were needed to use PowerPoint. Fifth, PowerPoint has a symbiosis partner: the use of the Internet. The support of the Internet made the use of PowerPoint more interactive, dynamic and easier for incidental learning, which was greatly favored by teachers and students. Sixth, some teachers made creative uses of PowerPoint besides presentation, including using it for games, quizzes, and student collaboration projects. These creative uses significantly improved the adaptability of PowerPoint and expanded the niches it served. In summary, the benefit of using PowerPoint was gradually increased and the cost decreased.

By the end of the academic year, the use of PowerPoint was ubiquitous, while overhead projectors were removed from most of the classrooms. One exception was the math classrooms. Math teachers still used the overhead projector from time to time because it was easier to sketch on transparencies than on PowerPoint. Overhead projectors survived in math classrooms because they served a special niche that could not be replaced by PowerPoint at this moment.

Case 2: Aspire

The Aspire program was mentioned by all teachers interviewed. It is an online course management system which was introduced into this school at the beginning of 2003-2004 year. The Aspire program has the following main functions: discussion boards, student-teacher communication, teacher-parent communication, class management, and grade book.

The invading of Aspire was a serious disruption to the school ecosystem equilibrium. Before Aspire was introduced in the school, teachers were very comfortable with the technologies they used for the tasks that Aspire was going to take over: they handed assignments to students in class, every teacher had a homework hotline so students and/or parents could check assignments by telephone; they used Grade machine to record and manage student grades; teachers and parents communicated mainly by means of the telephone or by appointments. Teachers, students, and parents were all very comfortable with what they had, and equilibrium was kept well. When Aspire entered this system, most teachers did not use it for various reasons. Some teachers expressed doubts, even distrust towards it. For example, one teacher said: "At first I didn't use Aspire because I didn't trust it. I was afraid that the system would crash and I would lose all my grades." One teacher said it was difficult to use and he would rather stay with grade machine; and another teacher said it was too time-consuming to set up.

Things gradually changed because of a number of reasons: First, to help teachers, parents and students use the Aspire program, the school had a series of training sessions within the school. These training sessions provided all groups of users with knowledge and skills for using Aspire. Second, there was pressure from the school: teachers were "strongly encouraged" to use Aspire, so a few more technologically adventurous teachers started to explore with it. Once these few teachers started using it, they posed peer pressure on the rest of the teachers. Meanwhile, since the Aspire program had a parent module from which parents could check their children's progress and grades, once this group discovered this function for one class, they wanted to use it for all classes; therefore, parents also posed pressure for all teachers to use Aspire. Third, with some knowledge and skills of using Aspire, and under pressure to use it, more and more teachers started playing with Aspire and exploring its functions. The more they explored with Aspire, the more advantages they found for this program. For example, the teacher who complained that using Aspire was too "time-consuming" at the beginning of the year found that "once you set it up, it actually saves your time because you don't have to e-mail every student about their grades or assignments, so I guess you pick up the time on the other end." The benefit of using Aspire gradually outgrew the cost as teachers' familiarity with Aspire increased.

The transition from established technologies to Aspire was by no means a quick or smooth one. At the end of the year, even when all teachers used Aspire, they used it differently. Some teachers only used the Aspire program to post students' grades, some teachers also used it for posting messages and assignments for students, and some teachers used most of the functions available, and one teacher even created a few student discussion rooms, assigned a specific topic to each discussion room, and asked students to post their responses.

Case 3: Instant Messenger vs. First Class –dead versus always prosperous

Instant Messenger was introduced into this ecosystem by students soon after they received the laptops and immediately started thriving. The instant popularity of Instant Messenger was based on the great niche it served: students at this age love to chat with their friends, and Instant Messenger provided them with a channel to chat with their friends anywhere and anytime—especially when they were bored in classes. In addition, this high-tech method of chatting was not only fun, but also very fashionable. So students spent so much time chatting through Instant Messenger that using Instant Messenger to communicate with their friends was taking too much of their time and energy, in other words, it was consuming too many resources. This developed into a serious problem, especially when teachers discovered that students were spending too much time chatting with their friends in other classrooms when they were supposed to be listening or participating in class activities. Then it became incompatible with the school philosophy and policies. So two weeks after the laptops were distributed, using Instant Messenger was banned throughout the whole school ecosystem. The rapid spread and growth of using Instant Messenger directly resulted in its extinction.

But, students soon found an alternative method to chat—e-mail. They sent e-mails to their friends and some of them checked their e-mails all the time. E-mail became a kind of messenger and the only drawback was that it was not "instant". It was still very convenient and quick because they checked it very often and replied to the messages right away.

In this case, what creates the use? Did the niche create the use, or did the use create the niche? On the one hand, students have the need to communicate with their peers. This need creates a possible niche for Instant Messenger, which provides a channel for student communication. On the other hand, the use of Instant Messenger expands this niche because it makes student communication available anywhere and anytime. They don't have to wait till recess to talk to their friends, nor do they need to meet their friends somewhere to talk. The expanded niche was kept even after Instant Messenger was taken away from students; then another species — the use of e-mail for quick communication - filled in this niche.

Summary

These cases illustrate how the use of one technology changed its immediate environment (the niche, users, relationships, etc) and the whole ecosystem, how these changes, in turn, changed the use of this technology, and how these changes resulted in further changes in the use of other technologies in this ecosystem. During this process, the factors from different sources work together, and influence how a technology use evolves from different angles. The evolution path of a technology use is determined by the ongoing dynamics of interactions between different factors.

These interactions not only shape the evolution paths of technology uses, but also change every component within this ecosystem. So far this chapter has mainly focused on discussing how different technology uses change over time and what influences their evolution. This is only a part of the big picture, in which all components of the whole ecosystem changed, the changes were connected with each other, and any change in one part of the system had some impact on the whole ecosystem and caused further changes. This big picture will be discussed in the following sections.

5.5 Discussion

Summary

Technology use in schools is not an independent series of isolated events or artifacts, but is situated in and connected with its context, and is an integral part of a network of changes. Technology use evolves. It's a complex ongoing process influenced by continuous interactions with other species, the users, and the environment.

The interactions and mutual influences between technology use, the users and the environment are not simple and linear, but are built upon circular causality and reflexivity. It is a cycle of changes, co-adaptation, and co-evolution. The school system is a network of changes, Different technology uses have different impacts on student outcomes. Therefore, the quality of technology use is a critical issue.

The ecological perspective can be a useful approach to the study technology use in schools. From the ecological perspective, it is easy to understand why technology innovations are not adopted or not used as much as expected. First, as an invading species, a technology innovation breaks the system equilibrium and creates disturbances, which may cause emotional uneasiness. Second, as a new species, it costs more resources; besides the investment of purchasing and installing technology, more investment is required for training, and teachers need to spend time and energy on learning the new technology. Third, teachers may not immediately recognizes uses for the new technology.

Limitations

This study has some practical limitations which may limit the generalizabiity of the findings. First, data were collected from only one school, so the environmental variables did not vary much, thus it was difficult to see how the environments at different school ecosystems affect the dynamics of technology use differently.

Second, this school had extremely rich technology resources that are not available to all schools; thus it was not a regular school that can represent most of the schools in the United States. However, this school may provide a glimpse of where all schools will be in the near future.

CHAPTER 6

IMPLICATIONS

Findings from this study have some important implications for policy making, technology integration and future research.

Implications for Policy Making

Successful technology use in schools depends, to a great extent, on a supportive policy environment. This study suggests that policy-making can support effective technology integration into schools though providing holistic support, providing ongoing technology planning, setting realistic and specific educational goals for technology use, and supporting more research on the quality of technology use.

Provide holistic support for technology use in schools to facilitate a virtue cycle and grow a healthy ecosystem. As results from this study show, technology use in schools is not independent nor a series of isolated events or artifacts, but is situated in and connected with the context, and is an integral part of an ongoing process of changes. The school system is a network of changes, so it is impossible to change one thing but keep others the same, and it is also impossible to achieve a goal, e.g., improving student achievement, through changing one factor at a time. Consequently, merely putting more technology into classrooms does not necessarily help to integrate technology in teaching and learning. Holistic support from all aspects of the ecosystem is critical in facilitating a cycle of changes and helping to grow a healthy ecosystem.

Provide ongoing technology planning. Since technology uses in schools constantly change and so do all of the other members of the ecosystem - the users, the school system, and the relationships between these subsystems - there is no "once and for all" solution to technology use in schools. A technology plan that works at one time may not work at another time. Therefore, it is important to provide ongoing technology planning and evaluation, to continuously refine current practices, and to provide timely support.

Be realistic about the impact of technology. Results from this study show that student performance, especially academic outcomes, are under the influence of many factors, and technology use is just one of these factors. It may not be possible to create direct and significant impact on student academic achievement through the use of technology. The impact of technology use on student outcomes is not determined merely by the particular technology, but is mediated by environmental factors, the users, and the technology, and by their constantly changing interactions and mutual influences. Therefore, it may be unrealistic to expect dramatic changes in student performance through one or two specific technology uses. Technology cannot revolutionize education, but it can cause changes that make the education system gradually evolve.

Set specific educational goals for technology use. Since different technology uses have different impacts on student outcomes, to facilitate technology use in schools and to accurately assess the effectiveness of specific technology uses, it is of crucial importance to set clear educational goals even before technologies are purchased. The decision-makers should ask questions such as what students need to learn, what abilities students need to develop, what daily tasks teachers need to perform, and how technologies can help achieve these goals and accomplish these tasks. Based on this information, clear educational goals and expectations can be set for specific technology uses. Consequently, teachers and students can have a clear understanding of the purpose of technology uses, and the impact of technology use can be assessed in more meaningful and practical ways.

Support more research on the quality of technology uses. Technology is believed to have great potential to help teaching and learning and great efforts have been made to promote technology use in schools. In the past the emphasis has been mainly on how much technology is used. Results from this study suggest that the quality of technology use is a more critical issue. Therefore, more policy efforts should be focused on improving the quality of technology use. Specifically, to improve the quality of technology use, more research on meaningful technology uses is required. The quality of technology use has begun to receive attention from educators and researchers, but empirical studies on this topic are still very scarce. Sufficient policy and financial support for this kind of research is important because a sound understanding of the quality of technology use is the premise of any effort to promote meaningful technology use. Second, education policy, to a great degree, determines how and how much schools integrate technology. With the acknowledgement of the importance of technology use quality on student learning, more policy emphasis should be placed on promoting meaningful technology uses in schools. For instance, when evaluating schools' efforts in technology integration, the criteria should not be solely on how much technology is used, but also on what and how technology is used. In addition, since education policy also influences how funds are allocated and spent, a focus shift from quantity to quality in educational technology policy and standards can help create necessary conditions for meaningful technology uses.

Implications for Technology Integration in Schools

Since technology use in schools is an ongoing process influenced by every components of the school system, it is of crucial importance to understand this process, to control factors that are positively related to student outcomes, and to grow a healthy ecosystem that facilitates virtue cycles and avoids vicious cycles. Findings from this study suggest the following:

First, before a new technology innovation is introduced into the school system, it is helpful to estimate what kind of technologies can be expected to survive in a particular school. Results from this study suggest that technology uses that serve an unoccupied niche (no serious competition), can adapt to a variety of environments (with high flexibility), and do not consume too many resources (low difficulty, high stability, user-friendly-designed, low tech support needed) are more likely to survive. It might also be helpful not to introduce different technology uses that serve identical purposes in order to mitigate species competition, and provide more complementary technology uses to facilitate symbiosis.

Second, after a technology is introduced into a school setting, it would be helpful to think about what we can do to help a technology use to survive. This study suggests that healthy interactions among species and between species with the environment are critical to the survival of technology uses. Healthy interactions can be facilitated through a number of approaches: a) Identify/create a niche for the technology use. Identifying the niche for the technology use helps users to see how a specific technology can be used for teaching and learning purposes. If there is no existing niche, can we create a niche through, for example, curriculum reform? b) Species characteristics might be altered in order to increase adaptability and to decrease resource consumption. For example, the Geometer's Sketchpad program was only available online during class time, so the use of this program was limited to places with Internet access and during specific time periods. If it were also available in CD-ROM format, then students could use it even without Internet access and at times more convenient to them. c) Decrease resource consumption of specific technology uses. This can be achieved in different ways. The technology programs can be designed to be more user-friendly so that it takes less time and energy for teachers, students, and parents to learn how to use them. Content-specific technology training can be provided to users to increase their familiarity with these technologies. d) The environment can also be changed to make it more supportive of technology use. The school can invest in the provision of timely and sufficient technology support. Teachers can form peer support groups and increase their social connectedness so as to obtain technology support from one another. e) Influence teachers and students' cost-benefit analysis. For example, the school administrator can recognize and articulate good technology use practices and specify the perceived advantages of technology uses. The cost of not adopting can be increased by policy changes. Experimental technology use in small groups of technologically proficient and innovative users can be formed. And administrators can provide more information regarding specific technology use so the users can make more informed decisions.

Third, since new technology innovations are invading species that disrupt system equilibrium, they may cause some unexpected or unwanted changes in the whole system. Therefore, when introducing new technologies into schools, educators must anticipate disruptions and changes in the school system, and prepare for the disruptions. Accompanying a new technology innovation, some changes and arrangements to things like school policies, class schedules, relocation of resources, and training sessions for teachers and staff might be necessary. Schools must make accommodations to use technology.

Fifth, the ultimate goal of technology integration into schools is to help students learn. Findings from this study suggest that the impact of technology use on student learning depends on how the technology is used. What is crucial to educational technology integration, therefore, is not how many technology innovations have been purchased, introduced, and installed, nor how much time is being spent on technologies, but how these technology innovations are used by students. Moreover, not all technology uses are equally useful to student learning. Therefore, the need to provide more resources and to create supporting environments for meaningful technology uses is of critical importance in schools. Specifically, school administrators, teachers, and parents should pay close attention to how students use technology, and to provide guidance to help students use technology more effectively and efficiently. In addition, new regulations and classroom disciplines may be necessary to help students resist distractions and make better use of available technology and resources.

Implications for Professional Development

To better help teachers make use of available technology, it is very important to help teachers make connections between technology uses and their teaching tasks (to locate a technology niche) and to help teachers make creative uses of technologies (to increase technology adaptability). Schools must provide the opportunities for teacher-technology interaction, show teachers specific ways of using technology so it can find the proper niche in classrooms and make it easier and less time-consuming for teachers to use technology. Teachers need assistance in making creative use of technology so it can adapt to different situations (Expand).

Suggestions for Future Research

Some important issues regarding the quality of technology use need more exploration. Specifically, more research needs to be done along the following lines.

First, technology should be studied in the context where it is used or not used. Technology use is situated in the context and its impact is interdependent with the specific conditions where it is used.

Second, further identify what technology uses are most educationally meaningful. This study shows that different technology uses have different impacts on different student outcomes. Therefore, the meaningfulness of technology use is contingent on the specific student outcome. Academic achievement should not be the only criterion for evaluating the meaningfulness or effectiveness of technology uses. Some other outcomes are also important components of school education, such as student behavior, attitude, self-esteem and career aspiration. Exploration of these aspects can enhance the effectiveness of using technology to help to develop complete learners.

Third, there is a need to explore and develop evaluation methods and instruments which evaluate student learning with technology. Student technology use and learning is experience-related and at times hidden or subtle; consequently, it can not be assessed through traditional outcome evaluation. Some alternative assessment methods such as performance assessment, essays and portfolios might be more effective in assessing student learning with and about technology.

CHAPTER 7

CONCLUSIONS

By studying technology use in schools as a function of evolutionary paths and ecosystem co-evolutions, this study and discussion has demonstrated that the introduction of technology sets in motion a wide range of changes. The emergence of new adaptations and complex attempts on the part of the school ecosystem environment and its inhabitants to ingest, absorb, explore, expand, or reject these changes creates certain measurable and predictable patterns. Demonstrably, only a few technology evolutions ultimately survive, and most undergo considerable adaptations. Where technology as a species survives, it changes the school ecosystem and extends its influence to all aspects of its environment.

If schools continue the recent dizzying upward spiral of technology investment, it will be worthwhile to study the evolutionary patterns of species, resources, users, policies, adaptations, and co-evolutions that result. The school ecosystem has, as has been described in detail here, elements which inevitably conflict with the technology species. But the tenacity of this species has been demonstrated under certain conditions, and one can easily imagine that this tenacity may increase as more and more teachers and students flick on machines, discover uses and applications, and encounter peer and institutional pressure to interact with the species.

It may be that future studies will reveal progeny in this environment that bare little resemblance to the species described in this research. Future teachers and students will approach their ecosystems with different needs, resources, perceptions, and abilities. The school ecosystem itself will undoubtedly be characterized by different environmental factors. And new technologies - always unpredictable - will doubtless have features and adaptative abilities that reflect some of the experiences gained from the pioneering generations. With each generation, the rules and parameters of the survival game change and undergo redefinition.

In this study, technology survival in a specific school environment was seen to be dependent on many environmental and adaptive factors. The research measured the adaptations and changes in sufficient depth to reveal the limitations of these measures and to identify several subtle, significant influences. Change one of these variables and a thriving species (like an overhead projector) may vanish, or a failing species (like a SmartBoard) may revive and flourish.

Teachers and students in this study learned to use some new technologies with ease, to court other ways of adapting to their school environment, and to react to changes in their views of the ecosystem. Other new technologies failed to thrive and became extinct. What mattered was the combination of factors and their mutual impact on one another. The next cycles are predicated by these: future adaptations and co-evolutions will incorporate the changes to the ecosystem and its inhabitants that resulted from these developments.

APPENDICES

Appendix A: Teacher and Student Variable Scales

Teacher scales (The numbers are the item numbers of these statements in the surveys.)

Positive belief:

1. Computers are generally reliable.

Social/Self aspect of tech use:

2. The more technology you use, the more respect you will get from other teachers.
3. The more technology you use, the more likely you'll get promoted.

Pressure on using tech:

4. My students know more about technologies than I do.
9. I need to use computers to keep up in this school.
10. Others in this school expect me to use computers.
11. My colleagues use computers more than I do.

Time constraint:

7. I have a schedule problem when using computers in my classroom.
8. If I use technology in my classroom, I may not be able to finish my teaching tasks.

Computer anxiety:

6. Using technology in my classroom is more likely to make myself look foolish.
12. I am not the type to do well with computer technologies.
19. I don't feel comfortable using computers in front of my students.

School rapport:

16. Most teachers here share my beliefs about what the central goals of the school should be.

Ng. attitude on tech: 18, 20, 22, 5, 17

5. I teach better WITHOUT technology.
17. It is difficult to integrate computer activities into most of my regular lesson plans.
18. I fear that computers and related technologies will isolate me from the students.
20. Computers and related technologies will isolate students from one another.
22. Students shouldn't be allowed to explore on computers by themselves.

(inverted the items and change negative attitude into positive attitude)

Computer interest: 21, 25

21. I am very interested in computers and related technologies.
25. I am interested in learning new technologies.

Tech support: 23, 24-

23. I have sufficient technology support in this school.
24. I would use technology more if I had more technology support.

Pedagogy: -32, -33, +34 (constructivist)
32. My students won't really learn the subject unless you go over the materials in a structured way.
33. It's my job to explain, to show students how to do the work and to assign specific practice.
34. I try to provide opportunities and resources for my students to discover or construct concepts for themselves.

School environment for new ideas: 13, -14, 15
<u>13</u>. We introduce many new things in this school.
-14. It is difficult to implement all of the new things in this school.
<u>15</u>. Teachers in this school are continually learning and seeking new ideas.

<u>Student scale:</u>

Life skills/ behaviors: 2, 13, 14, 17, 18, -19
2. I am well-behaved in class/school.
13. I follow instructions as they are given to me.
14. I think about the consequences before I make a decision
17. I know good/positive ways to handle my stress.
18. I say no when asked to do something I do not believe is right.
19. I hit or fight when I am angry.

Learning habits: 3, 11, 12, 16
3. I complete my homework on time.
11. I like participating in class activities.
12. I can ask questions to get the information I need.
16. I do my homework on my own.

Attitude toward school: 4, 6, 8, 9
4. Overall, I like school.
6. School is worth my time.
8. School is helping me.
9.The things I learn in school are useful to me.

Self-esteem: 5, 7, 10, 15
5. I am confident about myself.
7. I have high self-esteem.
10. I am confident about my ability to learn.
<u>15. I know my strengths.</u>

Computer Interest: 20
20. I am interested in working with technology/computers.

Self-rated computer ability: 1
1. I am very skilled with computers.

Appendix B: 5 Types of Technology Use

Table 15: 5 Types of Technology Use

Type	Technology Use
General Technology Use	Overhead projector for presentation
	PowerPoint for presentation
	ELMO for presentation
	Poster for presentation
	PowerPoint for taking notes
	Word for taking notes
	Internet for information
	Stickies to take notes
	Word for writing
Subject-related Technology Use	Learning with Geometer's Sketchpad
	Learning with Aleks
	Learning with Science probe
	Other software for learning
	Spreadsheet for data recording
Social/communication Technology Use	Telephoning teachers
	Emailing teachers
	Telephoning friends
	Emailing friends
	Chatting online with friends
Construction Technology Use	Creating websites
	Editing Movie/pictures
	Desktop publishing
	Doing artwork
	Programming
Entertainment/Exploration Technology Use	Download p/m/m
	Playing games
	Exploring new tech.
	Shopping online

Appendix C: Factors influencing 5 types of technology uses

Table 16: Factors influencing general tech use

Effect	Regression coefficient			t	p
$R^2 = 0.30$	β	SE(β)	Effect size		
(Constant)	1.821	1.496		1.217	.226
Student Pretest GPA	.166	.068	0.43	2.421	.017
Student technology interest	-.018	.035	-0.09	-.521	.603
Traditional pedagogy	.582	.343	0.30	1.696	.093
Constructivist pedagogy	-.310	.412	-0.13	-.753	.453
Teacher tech use T2	.002	.049	0.01	.039	.969
Teacher s/s effect of tech use T2	-.049	.071	-0.12	-.689	.492
Teacher negative attitude and computer anxiety T2	-.127	.121	-0.18	-1.050	.296
Teacher social connectedness and rapport T2	.189	.125	0.27	1.516	.132

Table 17: Factors influencing subject-specific tech use

Effect	Regression coefficient			t	p
$R^2 = 0.43$	β	SE(β)	Effect size		
(Constant)	-23.99	6.50		-3.69	.000
Parental involvement2	.16	.07	0.40	2.28	.025
Student Tech interest	-.08	.05	-0.26	-1.50	.135
Teacher FIT2	1.76	.63	0.49	2.78	.006
Tech interest2	4.73	1.21	0.69	3.91	.000
Tech support2	1.89	.58	0.58	3.29	.001
Traditional pedagogy	-.61	.37	-0.29	-1.64	.103
Constructivist pedagogy	1.26	.69	0.32	1.82	.072
Teacher general tech use	-.60	.17	-0.64	-3.63	.000
Time constraint2	-2.34	.74	-0.56	-3.16	.002
Teacher social connectedness T2	-.82	.58	-0.25	-1.42	.159

Table 18: Factors influencing social-communication tech use

Effect	Regression coefficient			t	p
$R^2 = 0.37$	β	SE(β)	Effect size		
(Constant)	-10.156	4.371		-2.324	.022
V.T.FIT2	-.156	.112	-0.25	-1.394	.166
VTanxty2	.673	.354	0.33	1.900	.060
Teacher tech interest2	2.234	.789	0.50	2.831	.006
Variation of Teacher technology interest2	-.563	.310	-0.32	-1.816	.072
Teacher perceived	1.065	.430	0.44	2.480	.015

technology support2 VTsppt2	.313	.276	0.20	1.131	.261
Variation of Teacher Time spent on technology2	-.269	.147	-0.32	-1.838	.069

Table 19: Factors influencing Construction Tech Use

Effect	Regression coefficient			t	p
$R^2 = 0.45$	β	SE(β)	Effect size		
(Constant)	-14.69	7.924		-1.854	.066
parent involvement2	.088	.086	0.18	1.022	.309
M.T attitude on laptop2	-5.13	1.916	-0.47	-2.678	.009
Variation of Teacher attitude towards the laptops2	1.39	.591	0.41	2.355	.020
Teacher technology anxiety2	4.36	1.613	0.48	2.705	.008
Variation of Traditional pedagogy2	-.79	.287	-0.49	-2.763	.007
M.T environment supporting innovation2	7.60	2.671	0.50	2.846	.005
VTenvmt2	1.14	.458	0.44	2.499	.014
M.T social connectedness2	4.25	1.273	0.59	3.338	.001
Teacher time on technology2	-4.73	1.532	-0.54	-3.086	.003
Variation of Constructivist pedagogy	.49	.231	0.37	2.101	.038
Teacher technology variety	1.47	.532	0.49	2.758	.007

Table 20: Factors influencing Entertainment/Exploration Tech use

Effect	Regression coefficient			t	p
$R^2 = 0.40$	β	SE(β)	Effect size		
(Constant)	-7.676	7.446		-1.031	.305
Teacher attitude on laptop2	2.337	1.476	0.28	1.584	.117
Teacher current technology use status2	2.840	1.165	0.43	2.437	.017
Variation of teacher current Tech use2	-1.492	.690	-0.38	-2.160	.033
Teacher tech interest2	2.206	1.041	0.37	2.119	.037
Teacher perceived tech support2	.849	.562	0.27	1.511	.134
Traditional pedagogy2	.669	.405	0.29	1.654	.101
Variation of constructivist pedagogy	.628	.327	0.34	1.923	.057
Teacher tech use variety	-.654	.364	-0.32	-1.798	.075

Appendix D: How technology uses affect student outcomes

Table 21: Factors influencing student GPA at the end of the school year (time 2)

Effect	Regression coefficient			t	p
$R^2 = 0.71$	β	SE(β)	Effect size		
(Constant)	5.735	2.243		2.557	.012
General tech use	.092	.159	0.10	.578	.565
Subject-Specific tech use	.023	.103	0.04	.218	.828
Social-Communication tech use	.120	.099	0.21	1.210	.230
Construction tech use	.002	.098	0.00	.023	.982
Entertain/Explore tech use	-.129	.095	-0.24	-1.361	.177
Traditional pedagogy	.258	.396	0.11	.653	.516
Constructivist pedagogy	-1.325	.579	-0.40	-2.289	.025
Teacher Tech use Variety	.126	.149	0.15	.847	.399
Teacher Common tech use	-.060	.099	-0.11	-.607	.546
Teacher time on tech T2	.383	.654	0.10	.585	.560
Student Development T1	.015	.068	0.04	.216	.830
Student time on computer T2	-.170	.057	-0.53	-2.991	.004
Student tech use variety	-.004	.019	-0.03	-.191	.849
Learning Habits T2	.307	.097	0.55	3.148	.002
FITness post	.088	.019	0.81	4.611	.000

Table 22: Factors influencing student technology ability at the end of the school year

Effect	Regression coefficient			t	p
$R^2 = 0.38$	β	SE(β)	Effect size		
(Constant)	8.051	1.995		4.036	.000
General tech use	1.416	.774	0.32	1.829	.071
Subject-Specific tech use	-1.291	.533	-0.43	-2.422	.017
Social-Communication tech use	-.280	.504	-0.10	-.555	.580
Construction tech use	-.596	.495	-0.21	-1.206	.231
Entertain/Explore tech use	.322	.449	0.13	.718	.474

Table 23: Factors influencing student learning habits at the end of the school year

Effect	Regression coefficient			t	p
$R^2 = 0.69$	β	SE(β)	Effect size		
(Constant)	2.542	2.468		1.030	.306
General tech use	.108	.176	0.11	.611	.543
Subject-Specific tech use	.027	.114	0.04	.234	.815
Social-Communication tech use	-.059	.110	-0.09	-.535	.594

Construction tech use	-.097	.108	-0.16	-.899	.371
Entertain/Explore tech use	.290	.100	0.51	2.894	.005
Traditional pedagogy	-.195	.438	-0.08	-.444	.658
Constructivist pedagogy	.115	.641	0.03	.179	.858
Teacher Tech Use variety	-.094	.165	-0.10	-.571	.569
Teacher common tech use	.131	.109	0.21	1.199	.234
Teacher time on tech T2	-.287	.723	-0.07	-.396	.693
Student development T1	.401	.062	1.14	6.465	.000
Student time on computer 2	.060	.062	0.17	.963	.338
Student tech use variety	-.008	.021	-0.07	-.394	.695
Student FITness T2	.022	.021	0.19	1.062	.291

Table 24: The impact of technology uses on student developmental outcomes

Effect	Regression coefficient			t	p
$R^2 = 0.86$	β	SE(β)	Effect size		
(Constant)	-5.844	1.21		-4.84	.000
General tech use	-.025	.149	-0.03	-.17	.869
Subject-Specific tech use	-.018	.103	-0.03	-.18	.859
Social-Communication tech use	.190	.097	0.35	1.96	.053
Construction tech use	.000	.098	0.00	-.002	.999
Entertain/Explore tech use	-.046	.095	-0.08	-.48	.631
Student Tech interest	.100	.049	0.36	2.04	.044
Student Learning Habits T2	1.151	.092	2.19	12.45	.000
Student GPA T2	.000	.095	0.00	.002	.998
Constructivist Pedagogy	.132	.310	0.08	.43	.671

REFERENCES

Ager, R. (1998). *Information and Communications Technology in Primary Schools: Children or Computers in Control*? David Fulton Publishers.

Anderson, R.E., & Ronnkvist, A. (1999). The presence of computers in American schools. Irvine, CA: Center for Research on Information Technology and Organizations, University of California, Irvine.

Becker, H. J. (1998). Running to catch a moving train: Schools and information technologies. *Theory Into Practice, 37*(1), 20-30.

Becker, H. J. (1999). Internet use by teachers: Conditions of professional use and teacher-directed student use. Irvine, CA: Center for Research on Information Technology and Organizations, University of California, Irvine, and the University of Minnesota.

Becker, H. J. (2000). Findings from the teaching, learning, and computing survey: is Larry Cuban right? *Education Policy Analysis Archives*, 8(51), p.2-32

Becker, H. J. (2001). How are teachers using computers in instruction. Paper presented at the Annual Meeting of the American Educational Research Association, Seattle.

Becker, H. J., Ravitz, J. L., and Wong, Y. (1999). Teacher and teacher-directed student use of computers and software. Irvine, CA: Center for Research on Information Technology and Organizations, University of California, Irvine, and the University of Minnesota.

Bennett, N. D., Kelly. (1997). Habits of mind--using multimedia to enhance learning skills. *Learning and Leading with Technology*. 24: 18-21.

Berliner, D. C., & Biddle, B. J. (1995) *The Manufactured Crisis: Myths, Fraud, and the attack on America's public schools*. Longman.

Berman, P., & Pauley, E. W. (1975). Federal programs supporting educational change, volume 2: factors affecting change agent projects, Santa Monica, California, Rand Corporation, Report, E(E).

Besser, H. (1993). Education as Marketplace. in Muffoletto, R., Knupfer, N. (1993) *Computers in education: Social, historical, and political perspectives*, New Jersey: Hampton Press.

Bronfenbrenner, U. (1979). *The Ecology of Human Development.* Harvard University Press.

Bruce, B .& Levin, J. A (1997). Educational technology: Media for inquiry, communication, construction, and expression. *Journal of Educational Computing Research.*17(1) 79-102

Bruce, B.C. (1993). Innovation and social change. in Bruce, B. C., Peyton, J.K., & Batson, T. (ed.) *Network-Based Classrooms: Promises and realities.* Cambridge University Press

Bruce, C. B. & Hogan, M. P. (1998). The disappearance of technology: toward an ecological model of literacy. In Reinking, D., McKenna, M. C., Labbo, L. D., & Kieffer, R. D. (Edi.) *Handbook of Literacy and Technology*. Lawrence Erlbaum Associates, Publisher.

Bruner, J.S. (1996). *The Culture of Education*. Cambridge, Mass: Harvard University Press.

Burbules, N. and Callister, Jr., T. (2000). *Watch IT: The promises and risks of new information technologies for education*. Boulder, Colorado: Westview Press.

Butler, D. L., & Cartier, S. C. (2004). Promoting Effective Task Interpretation as an Important Work Habit: A Key to Successful Teaching and Learning. *Teachers* College Record. 106(9): 1729-58.

Byrom, E. (1998). *Factors influencing the effective use of technology for teaching and learning: Lessons learned from the SEIRTEC intensive site schools.* Greensboro, NC: SERVE, Inc.

Christensen, C. A., Massey, D. R.; & Isaacs, P. J. (1991). Cognitive strategies and study habits: an analysis of the measurement of tertiary students' learning. *The British Journal of Educational Psychology*. 61, 290-9.

Coley, R., Cradler, J., and Engel, P. K. (1997). *Computers and classrooms: The status of technology in U.S. schools*. Policy information report. Princeton, NJ: Educational Testing Service.

Collis, B.A., Knezek, G.A., Lai, K., Miyashita, K.T., Pelgrum, W.J., Plomp, T., & Sakamoto, T. (1996) *Children and Computers in School*. Lawrence Erlbaum Associates, Publishers Mahwah, New Jersey.

Conway, P. & Zhao, Y. (in press). From Luddites to Designers: Portraits of Teachers and Technology in Political Documents. In Zhao, Y. (ed). *What Should Teachers Know about Technology: Perspectives and Practices.* Greenwich, CT: Information Age Publishing. 14-30.

Cuban, L. (1986). *Teachers and Machines: The classroom use of technology since 1920.* Teachers College, Columbia University, New York and London.

Cuban, L. (1999). The Technology Puzzle: Why is greater access not translating into better classroom use? *Education Week*, pp. 68, 47.

Cuban, L. (2001). *Oversold and Underused: Computers in the Classroom*. Harvard University Press.

Darwin, C. (1965). *The origin of species by means of natural selection, or the preservation of favoured races in the struggle for life.* Edited and abridged by Irvine C. & Irvine W. Frederick Ungar Publishing Co.

Frank, K. Zhao, Y., & Boreman, K. (2003 Winter). Social Capital and the Implementation of Computers in Schools. *Sociology of Education*. 77(2), 148-171.

Harris, J. B., & Grangenett. (1999). Correlates with use of telecomputing tools: K-12 teachers' beliefs and demographics. *Journal of Research on Computing in Education*, 31(4), 327-340.

Honey, M., & Moeller, B. (1990). *Teacher's beliefs and technology integration: Different values, different understandings* (Technical Report 6). New York: Center for Children and Technology.

Iansiti, M. (1998) *Technology integration: making critical choices in a dynamic world*. Harvard Business School Press.

Keiny S. (2002). *Ecological Thinking: A new approach to educational change.* University Press of America.

Leamnson, R. N. (1999). *Thinking about teaching and learning : developing habits of learning with first year college and university students.* Stylus Pub, United States.

Levin, J. A. & Bruce, B. C. (2001). *Technology as media: the learner centered perspective*. Paper presented at the 2001 AERA Meeting, Seattle WA

Lewontin, R. (2000). *The Triple Helix: Gene, Organism, and Environment.* Harvard University Press.

Margerum-Leys, J., & Marx, R. W. (2003). Teacher knowledge of educational technology: a case study of student/mentor teacher pairs. In Zhao, Y. (ed). *What Should Teachers Know about Technology: Perspectives and Practices*. Greenwich, CT: Information Age Publishing. P. 123-160.

Miller, L., & Olson, J. (1994). Putting the Computer in its Place: A study of teaching with technology. *Journal of Curriculum Studies*, p. 121-141

Nardi, B. A., & O'Day, V. L. (1999). *Information Ecologies*. The MIT Press.

Odum, E. P. (1975). *Ecology: the link between the natural and the social science.* Holt, Rinehart and Winston. New York

Odum, E. P. (1997). *Ecology: a bridge between science and society.* Sinauer Associates, Inc. Publishers. Sunderland, Mass.

OPA: On Purpose Associates. http://www.funderstanding.com/constructivism.cfm

Papert, S. (1992). *The children's machine: rethinking school in the age of the computer.* New York : BasicBooks

Pelgrum, W. J., & Plomp, T. (1996). Information Technology and Children From a Global Perspective. In Collis, B.A., Knezek, G.A., Lai, K., Miyashita, K.T., Pelgrum, W.J., Plomp, T., & Sakamoto, T. *Children and Computers in School.* Lawrence Erlbaum Associates, Publishers Mahwah, New Jersey.

Pelto, P. J., & Muller-Wille, L. (1972). Snowmobiles: Technological Revolution in the Arctic. In *Technology and Social Change.* The Macmillan Company. p.165-200.

Peyton, J. K., & Bruce, B. C. (1993). Understanding the multiple threads of network-based classrooms. in Bruce, B. C., Peyton, J.K., & Batson, T. (ed.) *Network-Based Classrooms: Promises and realities*. Cambridge University Press.

Piaget, J. (1964). *Development and Learning.* In R. Ripple & V. Rockcastle (Eds.), Piaget Rediscovered (pp. 7-19): Cornell University

Prawat, R. (1992). Teachers' beliefs about teaching and learning: a constructivist perspective. *American Journal of Education.* V.100 p.354-95.

Resnick, L. (1987). *Learning in school and out.* Educational Researcher, 16(9), 13-20.

Rodkin, P. C., & Hodges, V. E. (2003). Bullies and Victims in the Peer Ecology: Four Questions for Psychologists and School Professionals. *School Psychology Review*, Vol. 32.

Rogers, E. M. (1995). *Diffusion of innovation*. The Free Press.

Russell, M., Bebell, D., O'Dwyer, L., & O'Connor, K. (2003). Examining teacher technology use: Implications for preservice and inservice teacher preparation. *Journal of Teacher Education*, Vol.54, No.4, September/October, p.297-310.

Schofield, J. W. (1995). *Computers and Classroom Culture.* Cambridge University Press.

Schofield, J. W., & Davidson, A. L. (2001). *Bringing the internet to school—lessons from an urban district.* Jossey-Bass.

Tan, S., Lei, J., Shi, S., & Zhao, Y. (2003). The Adult-Children Tension: Activity Design and Selection in After-school Programs. Paper accepted for presentation at American Educational Research Association Annual Meeting, Chicago, April 19-23.

Tyack, D. B., & Cuban, L. (1997). *Tinkering toward Utopia; a century of public school reform.* Harvard University Press.

U.S. Congress, Office of Technology Assessment. (1995). Teachers and technology: Making the connection (OTA-EHR-616). Washington, DC: U.S. Government Printing Office.

U.S. Department of Education, National Center for Education Statistics. (2000). Teachers' tools for the 21st century: A report on teachers' use of technology. Washington, DC. Retrieved February 17, 2004, from http://nces.ed.gov/surveys/frss/publications/2000102/

U.S. Department of Education, Office of Educational Research and Improvement. (1993). Using technology to support education reform (Contract No. RR91172010). B. Means, J. Blando, K. Olson, T. Middleton, C.C. Morocco, A.R. Remz, and J. Zorfass. Washington, DC.

Urban-Lurain, M. (2003). Fluency with information technology: the computer science perspective. In Zhao, Y. (ed). *What Should Teachers Know about Technology: Perspectives and Practices.* Information Age Publishing. P.53-74.

Willis, J.; Thompson, A.; & Sadera, W. (1999). Research on technology and teacher education: current status and future directions. *Educational Technology Research and Development* v. 47 no4 p.29-45

Zhao, Y, Mishra, P., & Girod, M. (2000). A Clubhouse is a Clubhouse, a Clubhouse. *Journal of Computers and Human Behavior*, 16(3), 287-300.

Zhao, Y. & Cziko, G. A. (2001). Teacher adoption of technology: A Perceptual-Control-Theory perspective. *Journal of Technology and Teacher Education*, 9(1), 5-30.

Zhao, Y. & Frank, K. (2003). Factors affecting Technology Uses in Schools: an ecological perspective. *American Educational Research Journal.* winter, vol. 40. no.4, pp.807-840

Zhao, Y. (2003a). What Teachers Need to know about Technology? Framing the question. In Zhao, Y. (ed). *What Should Teachers Know about Technology: Perspectives and Practices.* Greenwich, CT: Information Age Publishing.

Zhao, Y., Frank, K., & Ellefson, N. (In press). Fostering Meaningful Teaching and learning with technology: Characteristics of Effective professional Development Efforts. In Floden R. & Ashburn, E. (Eds.). *Leadership for Meaningful Learning with Technology*. Teachers College Press.

Zhao, Y., Kendall, C., & Tan, H. S. (2003). Educational Technology standards for teachers: Issues of interpretation, incorporation, and assessment. In Zhao, Y. (edi.) *What teachers should know about technology? Perspectives and practices*. Information Age Publishing. P. 31-44

Zhao, Y., Pugh, K., Sheldon, S. & Byers, J. L., (2002). Conditions for Classroom Technology Innovations. Teachers College Record. 104(3), 482-515.

Zhao, Y., Tan, S. H., & Mishra, P. (2000). Going Beyond the Teacher's Machine. *Journal of Adult and Adolescent Literacy*. 44(4). Also appearing in Reading Online: http://www.readingonline.org/electronic/elec_index.asp?HREF=/electronic/jaal/12-00_Column/index.html

Zhao, Y., Tan, S., Lei, J., Shi, S., & Martineau, J. (2003). Evidence of Learning: Studying Learning Outcomes of an After-school Program. Paper accepted for presentation at American Educational Research Association Annual Meeting, Chicago, April 19-25.