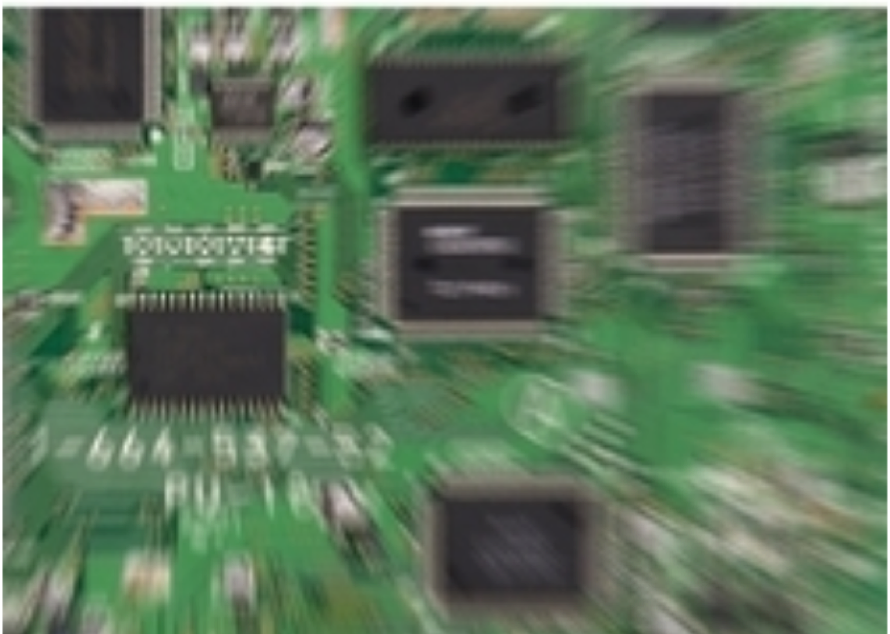
Efficacious Technology Management:

A Guide for School Leaders

Gary Ackerman



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INTRODUCTION

Efficacious educational technology supports, enables, and facilitates students as they are become full participants in the computer and network-rich communication landscape of society. Differences between how IT is provided and managed in other organizations compared to educational organizations can pose challenges for school leaders and the IT professional they hire from other industries. It is through the collaborative efforts of educators, information technology professionals, and school leaders that educational technology becomes efficacious.

In 1993, Seymour Papert imagined two time-traveling professionals from 100 years earlier; he speculated the physician would be flummoxed by the activity and the technology in the 20th century medical clinic, but the teacher would find the activity and the technology in a 20th century classroom very familiar. Papert based his speculations on the degree to which medical practitioners had adopted and adapted to technological innovations compared to educational practitioners. In the decades since, we who work in educational technology have made some progress in creating schools that would flummox the teacher in Papert's tale, but the work is far from complete.

The technicians among us have deployed computers that connect to servers, switches, routers, and other network devices so the Internet is available from nearly every corner of nearly every classroom in nearly every one of our schools. We use sophisticated software to manage those networks; our networks store and protect all varieties of data about of students, our curriculum, and our operations. Further, our networks provide robust and reliable access to vast information and global interaction through devices that our schools own and that students, faculty, and staff own and bring to school. That information technology (IT) infrastructure has not, however, transformed teaching and learning in a manner that has been promised by so many advocates. The observation that much teaching and learning remains as it was prior to the arrival of digital tools continues to be made by scholars who study teaching and learning (Luckin, Bligh, Manches, Ainsworth, Crook, & Noss, 2012; OECD, 2015; Tondeur, van Braak, Ertmer, & Ottenbreit-Leftwich, 2017).

The laggardly rate at which technology has changed what happens in classrooms may not be surprising, however. Larry Cuban, a well-known scholar from Stanford University, studied the effects of electronic media (radio, television, and movies) on education earlier in the 20th century and found them to be inconsequential. He noted, “Claims predicting extraordinary changes in teacher practice and students’ learning, mixed with promotional tactics, dominated the literature in the initial wave of enthusiasm for each new technology” (Cuban, 1986, p. 4), but observation proved these tools were no better than teachers using other information technology at conveying information. Something appears different, however, about the computers and digital networks we have today compared to earlier media. For the most part, earlier electronic media did not become as widely used for official purposes in the way that digital technology has become the default for legal and governmental communication. Nor did it become so widely adopted for interaction, nor did it become widely used for people to create information in the way that digital technologies have. Previous generations of American citizens listened to the radio for entertainment as they completed paper copies of their income tax returns which were mailed to the Internal Revenue Service. Now, we listen to streaming media and carry on conversations over text messaging as we complete and file our tax returns via the Internet. In those areas where IT infrastructure has been installed it has come to dominate all aspects of economic, political, social, and cultural life.

The leaders of almost every school face the same challenging situation: They must create schools that reflect the dominant role of digital IT in society and they must prepare students for that world; but the changing landscape of teaching, inadequate technical expertise, and limited resources are genuine barriers to this work. What we know, how we know it, and what we know about learning is advancing at a rate that fast outpaces teachers' capacity to respond to it. Operating and maintaining the IT systems in schools requires expertise that is far beyond that of the "tech-savvy" teachers who managed the first IT systems installed in schools. IT professionals who are "imported" into education from other businesses and industries often find the practices, assumptions, and expectations that served them well in other settings do not transfer into education. Teachers and students are different from other workers, and the IT (including the hardware, the software configurations, and the personnel) they rely on for their work must accommodate those differences. IT is also a capital-intensive aspect of operating schools. Devices and network upgrades can consume years' worth of technology budgets in a short time, and the total cost of ownership of devices places on-going demands on budgets. Further, technology introduces new and rapidly evolving regulatory and policy issues into school management.

The situation regarding IT management in many schools is well-captured by the hypothetical (and sarcastic) Putt's Law. According to Archibald Putt, "Technology is dominated by two types of people: those who understand what they do not manage and those who manage what they do not understand" (Putt, 2006, p. 7). Further, Putt articulated a corollary, "Every technical hierarchy, in time, develops a competence inversion" (p. 7). While these words are intended to be humorously cynical observations, they do describe the current state of IT management in schools:

- Technology professionals configure IT systems for students and teachers, but they are unfamiliar with emerging technology-rich pedagogy. In Putt's terms, IT professionals are managing devices for purposes they do not understand.

- Educators complain about the IT systems in schools, but they don't understand the complexity of managing IT systems, the potential conflicts and threats to the operation of enterprise IT, and general chaos that can result when enterprise networks are not tightly controlled. In Putt's terms, educators seek to manage IT they do not understand.

- School leaders make budget and personnel decisions that impose unrealistic limits on IT professionals and they advocate for practices beyond the capacity of the available IT or are contrary to the professional tendencies of the teachers.

The schools in which students participate in the digital world are places in which IT infrastructure is available and functioning; the existence of this infrastructure is absolutely dependent on skilled IT professionals to operate and maintain it. These schools are also absolutely dependent upon skilled educators who plan and facilitate learning experiences in which all students access, manipulate, analyze, create, and disseminate information using the IT. To improve efficacy in these schools, teachers' critiques of the of the IT they use as well as their requests for new features must be accommodated by IT professionals because educators best understand how the IT effects students. Further, these are schools are absolutely dependent upon school administrators understand the demands of maintaining IT in an operational state as well as the emerging needs of teachers. Together; educators, IT professionals, and school administrators must collaborate for efficacious technology management in schools.

Efficacious IT Management

Within any organization, leaders define a small number of strategic goals; these indicate the conditions they seek to make true and the success of the organization is determined by the degree to which these goals are accomplished. When an organization achieves its strategic goals, we recognize the leaders and members have been efficacious. Throughout this book, I refer to "efficacious IT managers" which is a group comprising teachers, IT professionals, and school leaders whose decisions and actions lead to the strategic goals being realized

Each community defines its own strategic goals, but I fully expect every reader of this book is associated with (or hopes to become associated with) a school in which leaders have articulated a strategic goal such as "Students will fully participate in the communication life of our society which is dominated by digital information technologies." (My choice of words models John

Dewey, who is credited with saying "Education is not preparation for life; education is life itself." Therefore, the strategic goal is written to *participate* in the information life of society, not simply to *prepare* students for it.)

This book was written to support school professionals (educators, technicians, and leaders) as they become efficacious IT managers. It concerns both the decisions they make and the actions they take to ensure the information technology infrastructure installed in schools is useful to teachers as they work with learners as they become citizens in the emerging digital world. This book is intended to help IT professionals understand the world of education and for educators to understand the world of IT.

Because strategic goals are generally too broad to guide meaningful action, planners define logistic goals. In situations where the logistic goals are aligned with the strategic goal, there will exist a positive association between achieving the logistic goals and achieving the strategic goal. With regards to information technology in schools, logistic goals must ensure decisions are made and actions taken to create technology that is appropriate, proper, and reasonable (see figure 1).

- Teachers (whose who spend their days working directly with students) steer decision-making processes so that IT systems are appropriately configured to be useful for the curriculum they teach, the pedagogical methods they employ, and the developmental circumstances of their students.

- IT professionals implement decisions so that IT systems are *properly* configured; this ensures the IT is operational, it functions as expected, and it is secure.

- School administrators govern decision making to ensure IT systems are *reasonably* configured and supported to meet the needs of learners and to reflect local priorities and limits. Reasonableness is a relative term and it is defined locally; budgets, existing policy and procedure, and similar factors affect what is deemed reasonable.

A situation I encountered when writing an early draft of this book serves to illustrate how proper, appropriate, and reasonable

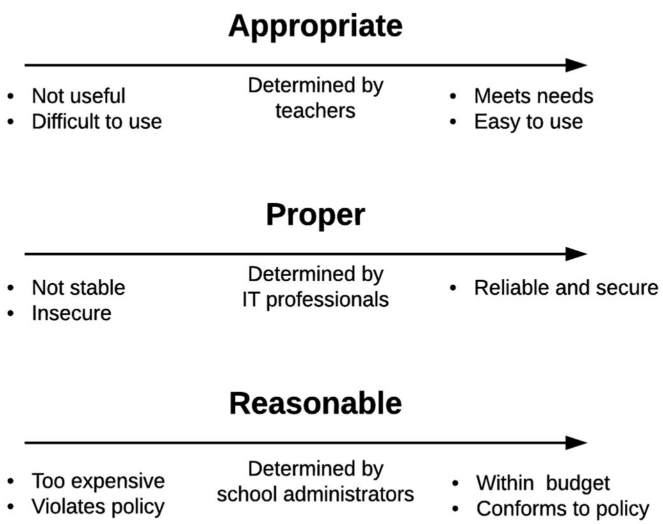

Figure 1. Dimensions of efficacious IT management

configurations of IT can influence teaching and learning. I was asked to help resolve some “network problems” in a school. Math teachers had complained that students could not access the online grade book from the computers provided under the recently begun one-to-one initiative. It turned out the network administrator had configured the permissions and switching so that students were unable to access the online grade book while at school. He reasoned, “We need to prevent students from trying to ‘hack’ their grades.” The principal responded, “That seems an insignificant threat, and it prevents students from tracking their grades when they are here at school. It is essential they be able to see their grades while in class with their teachers present” and he directed the network administrator to reconfigure the network. In this case, the network administrator properly configured the network (he had successfully prevented students from accessing the server), but the configuration was inappropriate (it prevented access to information necessary for teaching and learning), and it was deemed unreasonable (thus the school administrator who had authority insisted the configuration be changed).

The Barriers to Efficacy

If information technology is to facilitate realization of the strategic goal of allowing students to fully participate in the digital world, then it must be appropriately used, properly configured, and reasonably supported. Deficiencies in any of these aspects of technology management threaten the overall efficacy of the IT managers. To ensure those with expertise in all three aspects of IT management are involved in planning, decision-making, designing and implementing interventions, most schools convene technology planning committees. These groups have made schools that are physical places rich with screens and connections to online spaces. Even in those schools served by well-functioning committees, technology management may not be as efficacious as it could be; it can be inefficient, ineffective in some areas, and incomplete for some populations of students. I have come to conclude the root cause of much inefficacy is lack of shared understanding among the disparate professionals involved in IT management.

Fundamentally, educators and IT professionals understand technology different ways. Even steps that seem to be necessary for reliable and secure computers can be differently perceived and understood by different groups. Consider complex passwords; IT professionals perceive them to be a simple method for keeping the network secure (which they do), but teachers can find them to be an impediment to quick access, especially for those students with emerging keyboarding skills. Consider, as well, the example of operating systems. Installing operating system updates in a timely manner as an essential step of keeping systems secure, thus reliably available. Teachers, however, who find their lesson delayed as they wait for computers to finish installing updates before they can begin will see them as interfering with the reliability of the machines (of course updates are becoming less disruptive as school have adopted Internet-only notebooks). The school administrator who is an enthusiastic user of his or her tablet for personal and professional and work may not understand the difficulty of managing those devices in multi-user environments; this leads IT professionals to push back against his or her suggestion tablets be purchased for students.

Negotiating what is appropriate, proper, and reasonable is difficult when the participants in the management decisions approach the problem from different perspectives, have different concepts of the same terms, and interpret the same circumstances differently. Efficacious IT management is also made more difficult because of the disparate approaches to problems solved by the three groups who must collaborate for efficacious IT management.

Designing IT systems is a typical tame problem (Rittel & Weber, 1973); it is well-understood and systems are designed using known procedures. IT professionals can clearly describe the networks they seek to build and maintain, and the procedures for building and troubleshooting computer networks can be transferred reliably from one design project to another. Further, IT systems can be tested and redesigned before they are deployed to users. Teaching, on the other hand, is a wicked problem; it is not clearly understood, there are multiple and interconnected factors that affect how its effectiveness is judged, and those factors are incompletely known. Further, different individuals will judge the same outcomes differently. Successful teaching depends on learning (which is both a physiological and a psychological process as well as social one), and many educators recognize the best teaching does not always influence learning in the intended manner. School leadership is largely a political process, so the way it proceeds and the measures of success are entirely dependent on perceptions, power, and priorities.

Because of these fundamental differences in their work, technology professionals, teachers, and school administrators can find their IT management is affected by the silo effect. For most of their work hours, these professionals work in separate locations and they apply different knowledge and skills to the problems and accomplish the tasks specific to their area of expertise. While educators, IT professionals, and school leaders all assume responsibility for effectively and efficiently realizing their logistic goals, the nature of those goals and their connection to the strategic goal must be understood collectively if IT management is to be efficacious.

Becoming Efficacious

The isolating silo effect is also necessary for efficacious IT management. Few individuals are capable of (or interested in) solving the problems encountered by those in the other groups, so multiple individuals comprise efficacious technology planning teams. The IT we install is vastly more complex than the first computers that arrived in schools; without highly skilled technicians, our digital networks will fail. Teaching is far more complex than it was previously; we have more to teach, more cognitive tools that must be accommodated, and we teach brains that are profoundly affected by the IT which defines their world both in and out of our classrooms. The skills and knowledge and habits of mind necessary to negotiate this dynamic milieu of technology and ideas does not exist in any one person. Efficacious IT management, we can conclude, requires collaboration.

For teachers, IT professionals, and school leaders to make decisions and take actions that build effective digital learning environments, they must build a common language and understanding of the nature of the problems and how acceptable solutions will be recognized. When school IT managers share understanding of what needs to be done, what everyone can expect to see when it is done, and how they should approach the work, they will be more successful in achieving strategic goals.

Through this book, I seek to support those who are interested in generating common language, understanding, and actions so that communities realize the goal of creating and sustaining schools that are places and spaces for digital learning. I define the context in which educational technology is used, the dimensions of educational technology, and the processes that can facilitate this collaboration. My work is grounded in assumptions about the users of IT in educational institutions and it recognizes the role of theory in IT management.

My Assumptions About Users of School IT

The education and experience that prepares IT professionals to properly configure IT infrastructure in schools is unlike the professional preparation of educators. To earn teaching credentials, educators must complete undergraduate and graduate programs at accredited institutions of higher education, pass tests, and meet other requirements specified by the regulatory agencies that grant teaching licenses.

The government oversight that marks educator licensing is not required for those who work with IT systems in schools. IT professionals become qualified to enter the field in two ways. First, they earn degrees from colleges and universities. Second, they pass exams created by professional organizations and companies that build and sell hardware and software. Interestingly, these two are not coincident. Consider an individual who earns an undergraduate degree in information systems. The graduate will have taken courses in network management, network security, databases, and other aspects of IT systems. Those courses are likely to be vendor-independent, so students learn the theory and practice of IT management common to all information systems. Cisco, the manufacturer of networking devices, certifies individuals who pass the exams they publish can properly configure the devices they sell, but make no claims about their other skills. The information systems graduates may be unable to pass a Cisco exam, but the degree program was not intended to prepare students for those tests. Because the contents of the tests are very specific, one may be able to pass a Cisco exam without holding a degree. Both individuals, however, may be qualified to properly configure IT systems in schools, but neither the undergraduate degree nor the Cisco exams address the needs of users in educational organizations.

IT professionals who arrive in schools are likely, also, to have experience working in fields other than education. While the steps needed to properly configure IT networks are the same regardless of the nature of the users, the appropriate configuration does depend on the nature of the users. The differences between users in schools and users in business are relevant to the design of IT systems, and IT professionals may find the configurations that were proper and appropriate in business are proper but inappropriate in schools, thus they must reevaluate what they believe to be the best practices for managing and configuring IT. The differences between users in business and industry and those in educational organizations (especially K-12 schools) are based on both the skill levels of the users and the nature of teaching and learning as information tasks. These differences are summarized in table 1.

Some users of school IT do resemble users in other businesses and organizations; for example, in the business office of any school, there are professionals who manage finances. Those individuals need access to accounting software, so they can process invoices and pay bills just as finance professionals in all organizations. Those individuals will know the task they are assigned and will have been trained in how to do it. They will do

Table 1. Comparing IT users in different organizations

Business and Industry	K-12 Education
Competent users Generally, adults have the general aptitude and literacy skills necessary for their jobs.	*Users with emerging competence* Especially in primary and elementary schools, users are first learning to read and write.
Predictable skills IT managers know what users are capable of doing.	*Unpredictable skills* IT managers do not know what users can do and very different users access the IT systems.
At-will users Users can be removed from situations in which their skills do not match the needs.	*Compulsory users* Attendance in generally mandatory for students, and schools enroll all students.
Function-driven need Needs are determined by the task each user is assigned.	*Interest-drive need* Students' and teachers' interests determine IT needs.
Known and stable need Users' need typically does not change.	*Unknown and unstable need* IT needs change as curriculum evolves and as users become more competent.

that job daily (with regular and predictable variation such as completing and distributing tax forms) and indefinitely. The computer room in an elementary school served by that business office will be used by students who are early in the process of learning to read as well as teachers who are working on graduate courses, so the users of the computer room have much more varied need.

Teachers are likely to vary their curriculum and instruction based on the needs of particular students and groups, and those may not be known until they meet the students and work with them for several weeks. Perhaps the most important characteristic of school users is the compulsory nature of being a student. Whereas underperforming business users can separate from the situation, the professionals responsible for school IT have a legal and moral obligation to provide appropriate IT environments and experiences for all students.

The Role of Theory

In the vernacular, "theory" is associated with ideas that are incomplete or not necessarily true. Among educators, and other pragmatic professionals such as technologists, theory is often associated with unrealistic or idealistic thinking that has little connection to their work. Those interpretations of theory are unfortunate, however, as theory can inform and focus decisions made by all who participate in school IT management. It is reasoned that making decisions and taking actions without addressing theory leads to inefficient and ineffective decisions and actions.

Grounding decisions and actions in theory allows decision makers to take advantage of three affordances that make it particularly useful for efficacious IT management in schools. First, every theory clearly identifies those factors that are relevant and that deserve managers' attention as they design interventions. Even when professionals are working within their field of expertise, they often overlook important factors, they dedicate resources to irrelevant factors, or they accept assumptions that have been disproven by research. Theory supports the design of interventions that focus on what matters and only what matters.

Second, theory allows IT managers to predict the changes that will be observed once decisions are implemented. Coincidently, theory suggests methods for collecting data that will confirm or refute those predictions. Although instruments designed to collect research data may not be appropriate for evaluating interventions in schools, theory has been elucidated with instruments and methods that can be can be adapted by IT managers as they seek to evaluate management decisions and actions in schools.

Third, theory affords explanations. The reason researchers do their work is to identify and support cause-and-effect relationships. While it is exceedingly difficult to establish cause-and-effect without experimenting (and true randomized double-blind experiments are unusual in education for a range of factors including ethical considerations), theory can facilitate our understanding why IT projects in schools failed or succeeded. If our predictions are accurate, then we explain them in terms of theory. If our predictions fail, then we use theory to understand what happened and why. In both cases, theory results in deeper understanding of our unique situations and the decisions we make and actions we take.

Several theories and frameworks relevant to IT management in schools are presented in this book. Educational technology is a field in which some work can be conducted from an atheoretical stance. The technician repairing computers has little concern for theory, but teachers' actions are informed by theory (even if it is not articulated). Theory, nevertheless, plays an important role in how managers undertake their work and in providing a structure within which technicians, teachers, and all others who contribute to the technology-rich school function. Without theory, IT managers are likely to abandon interventions before they have matured to the point where expected improvements are widely observed as they are distracted by emerging fads that promise unreasonable outcomes.

There are two theories have been widely applied to problems in educational technology and these can be used to explain and predict many situations and the results of many interventions in the field. When there appears to be no other theory to inform decisions and evidence, technology acceptance model and cognitive load theory can provide insight for IT managers.

Technology Acceptance

Technology acceptance model was first elucidated to understand the observation "that performance gains are often obstructed by users' unwillingness to accept and use available systems" (Davis, 1989 p. 319), and it has been used to study decisions to use (or avoid) technology in many settings. Variations of technology acceptance model have been used to develop and refine both IT systems (hardware and software) and organizational practices that rely on IT systems. It is used to predict and explain both how individuals interact with IT as well as patterns of IT use within groups, and it is used to change perceptions of technology and patterns of technology use.

In 2003, Venkatesh, Morris, Davis and Davis modified the TAM into the Unified Theory of Acceptance and Use of Technology (UTAUT); in this work, the scholars combined eight different theories that predict the decision to use technology into one model.

According to UTAUT, four factors are positively associated with the use of technology: performance expectancy, effort expectancy, social influences, and facilitating conditions (see figure 2).

- *Performance expectancy* is a measure of the extent to which an individual believes technology will affect his or her job performance in a positive manner. It is rooted in efficiency, relative advantage, and outcome expectations. Interventions that lead to increased efficiency or improved outcomes will be more used.

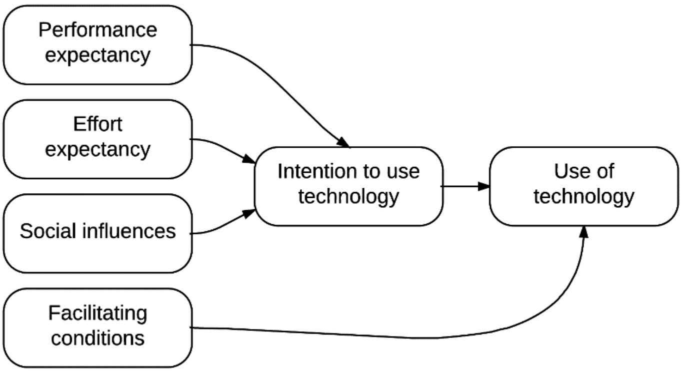

Figure 2. Factors directly associated with technology use (adapted from Venkatesh, Morris, Davis and Davis 2003)

- *Effort expectancy* is a measure of the individual's perceptions of how easy it is to use the technology; users intend to use systems they perceive to be easy-to-use.

- *Social influences* are related to the individual's perceptions of how others perceive the technology and its use; technology used by others who opinion is valued will be more used.

- *Facilitating conditions* include structures that provide responsive and effective technical support, adequate replacement plans, access to necessary training, and other supports. More and more highly functioning systems that maintain and provide technology in organizations are associated with increased use of it.

It is notable that these factors are associated with ones' intention to use a technology are based on each individual's perceptions. In a school, different populations and even different individuals within a population may perceive the same technology differently, and those differences will affect individuals' intentions to use the technology. Efficacious IT managers will use UTAUT as a theory to explain observed uses of technology and predict interventions that will change those patterns. Changes can be made to affect those factors, and failures to observe the expected changes can be evaluated for either effectiveness or perceptions of the changes.

Cognitive Load Theory

While technology acceptance is a theory that can explain and predict the decision to use a technology, cognitive load theory (Sweller, Ayres, & Kalyuga, 2011) (CLT) predicts and explains technology use once it has been adopted. CLT is based on the assumption that using information (and the information technologies used to communicate it) requires attention, perception, thought, and memory, thus it is a cognitive activity. Further, human cognition is a zero-sum quantity; each individual has a limited quantity of cognition available at any moment, and that cognition used for one purpose is not available for another purpose.

Theorists identify three types of cognitive load that characterize an information task:

- *Intrinsic cognitive load* is that which is necessary to understand the task and to use the information necessary to accomplish the task. Changing the task changes the intrinsic cognitive load, and steps taken to reduce it results in a different task.

- *Germane cognitive load* is that which is available for the learner to think about, strategize about, and come to deeper understanding of the ideas and information in the task. Learning occurs only when germane cognitive load is available and the amount available limits what can be learned.

- *Extraneous cognitive load* is that which is wasted by the learners managing bad design or poor organization of information or information technology tools. Using unfamiliar tools can also increase extraneous cognitive load.

When designing the information tasks and the information technology platforms that are used for teaching and learning, efficacious IT managers seek to minimize extraneous cognitive load and maximize germane cognitive load. It is reasoned that changing the intrinsic cognitive load is accomplished only by changing the task; therefore, reducing the extraneous cognitive load is the only method of increasing the cognitive load for germane purposes.

Consider the example of graphing calculators. Using this technology, one can minimize the extraneous cognitive load of drawing the graph of a sophisticated function, so more cognition can be dedicated to understanding the mathematics. When first encountering a graphing calculator (or when encountering an unfamiliar model), determining how to use the device increases extraneous cognitive load of graphing. This explains the practice of introducing such technology with simple and familiar examples. Once the technology and its operation along with the manner in which it displays information becomes familiar, the extraneous cognitive load of using it decreases, so the advantage of using it for sophisticated mathematics is realized.

As with all theory, CLT predicts and explains what may be observed in technology-mediated teaching. Devices may be unused and procedures may be avoided because they introduce excessive extraneous cognitive load. It also helps IT managers understand the changing perceptions of and uses of technologies; as technology solutions become more familiar (through training and familiarity) they should become more widely used.

The Organization of My Solution

When writing the book, I sought to answer three questions about educational technology. “Why do we need to plan for efficacious IT in schools?” In “Chapter 1: Information Technology, Society, and Schools,” I answer this by describing the active influences of computer and related technologies on humans and our organizations, including schools. My purpose for beginning with this chapter is to establish the context within which strategic goals must be defined and realized and to establish the complex nature of technology in schools and the nature of change within human organizations.

In the next five chapter, I describe the dimension of educational technology. These comprise those aspects of educational technology that IT managers must address. The chapters include: "Chapter 2: Technology-Rich Teaching and Learning," "Chapter 3: Access to Sufficient Computing Devices," "Chapter 4: IT Networks," "Chapter 5: Web Services," and "Chapter 6: Technology Support Systems." In these chapters, I answer the question "What systems must school and technology leaders create?" The focus of these chapters is largely on information technology infrastructure and the ancillary systems necessary to ensure logistic goals are defined to address relevant purposes. While some IT professionals will find this information insufficient to provide configuration advice, they will find it helpful to understand the level of expertise they can reasonably expect school leaders to demonstrate. Further, it deconstructs the many potential activities of IT managers so they focus on the essential tasks.

The final two chapters address the question "How should school and technology leaders approach planning and decision-making?" Progressive discourse, which is a model that allows for (and necessitates) shared understanding and valid evidence, is described in "Chapter 7: Discourse, Design and Data;" and some trends and generalization that inform all leadership and management decisions are considered in "Chapter 8: Understanding Change."

Chapter 1: Information Technology, Society, and Schools

Information technology exerts strong and active influences on the humans who experience it. In this chapter, I explore those effects and describe how they define aspects of economic, political, and cultural life as well as the schools that reflect those realities.

What we think, how we think, and what types of thinking we value depend largely on the nature of the information technology we experience. The effects of information technology on human cognition are so deep that many are unaware of the degree to which it affects us, or even that it affects us at all. Scholars refer to such deeply embedded aspects of civilizations as paradigm mediums. Brad Mehlenbacher (2010), a scholar at North Carolina State University, observed, "Once these developments are in place, it becomes exceedingly difficult to disentangle them from predictions about the future" (p. 7), and he continues, they "form the very core of our systems for understanding, conceptualizing and promulgating knowledge" (p.7). For individuals whose experience is immersed in these paradigm mediums, they determine what is expected of other people and what will comprise the environment they perceive to be natural.

Humans tend to become aware of the effects of paradigm mediums only during those periods when they change in significant ways or when they are replaced. The current generation of educators is working at the historical moment when digital information consumed on screens is replacing print information consumed on paper, and we are observing changes cognition and education similar to those observed throughout history when paradigm mediums changed. The strategic goals that focus efficacious IT management in schools will be grounded in emerging paradigm mediums and intended to allow students to participate in a world that is dominated by digital information. In this chapter, I explore the nature of the influences of information technology on society and its schools. Understanding the nature and extent of these influences will prepare school IT managers to articulate strategic and logistic goals that accurately reflect the technology-rich nature of society.

The role of microcomputers in curriculum and instruction has been debated since they first arrived in schools; some educators advocate for quick adoption of every new tool while others advocate for avoiding digital technology altogether. Disparate perceptions of emerging information technologies among educators is not a new phenomenon. In his 2011 book *The Information: A History, A Theory, A Flood*, James Gleick noted that Plato criticized those who sought to teach writing when he observed, “You have invented an elixir not of memory, but of reminding; and you offer your pupils the appearance of wisdom, not true wisdom” (p 30). The wisdom of Plato did not require writing. Gleick goes on to quote Thomas Hobbes, the 17th century philosopher, who commented on preliterate cultures (those that lack writing), “There was no method: that is to say, no planting of knowledge by itself, apart from weeds and common plants of error and conjecture” (p. 49). For Hobbes, no writing meant no wisdom. In the time between Plato and Hobbes, writing expanded throughout society, it disrupted patterns of information use, and redefined what it meant to be “educated.” Plato perceived writing as a degradation of human skills, so he rejected the emerging information technology and recommended that others reject it as well. In this, Plato lost. We can predict similar loss for those who advocate we avoid the technologies emerging today.

We are in the midst of a disruption similar to that caused by writing, and literacy skills that have been useful for generations are no longer sufficient. My grandfather graduated from the University of Vermont in 1939 and I have some of his textbooks on my bookshelves along with the textbooks I used while an undergraduate student at the same institution 49 years later. The content of the textbooks (we both studied biology) is vastly different, but the literacy skills useful for his books were equally useful for mine (including our shared habit of writing in our textbooks). While alternatives to print media have always played a minority role in curriculum, digital media are increasingly the mode of content, and are coming to dominate in some content areas. In a 2014 report on National Public Radio (Kestenbaum, 2014), the growing trend of publishers replacing printed textbooks with digital versions was detailed. Publishers are motivated by the single use nature of digital texts; each student who enrolls in a course must purchase access to digital textbooks whereas students can recycle printed textbooks until the professor adopts a new one.

The emergence of computers and other digital devices, the information accessed through them, and the capacity to rapidly manipulate information using them is challenging deeply held beliefs about cognition and learning. It is no longer tenable to argue that technology is marginal to the curriculum, nor is it tenable to use computers and associated technologies as an add-on to the curriculum to be used for enrichment purposes. It is only through using digital technologies to access, manipulate, create, and disseminate information that students fully participate in 21st century society. Because this shift from print to digital information is still incomplete and the technologies are still emerging, strategic goals for schools will be actively renegotiated to reflect changing technologies and associated societal expectations into the future.

Information Technology and Society

There can be little question that characteristics of our brains differentiate humans from other creatures. Increasingly, cognitive scientists recognize our brains are designed for the social interactions that have allowed humans to cooperate, and this cooperation has enabled our species to avoid extinction. Cognitive and developmental psychologist Michael Tomassello (2014) described the importance of social interaction for human nature when he observed, "Humans biologically inherit their basic capacities for constructing uniquely human cognitive representations, forms of inference, and self-monitoring, out of their collaborative and communicative interactions with other social beings. Absent a social environment, these capacities would wither away from disuse…." (p. 147). As much as we are a social species, humans are a technology-using species. It is through technology that humans have extended their capacity to manipulate and control the environment. These effects had led scientists to define the Anthropocene as the era in which humans are changing the world on a geologic time scale (Waters, Zalasiewicz, Summerhayes, Barnosky, Gałuszka, & Wolfe, 2016). When using information technology in the 21st century, humans are both social and technology-using at once. Through our IT, we interact with people across the globe just as quickly and easily as we can interact with individuals at the next room. In the next section, I present information technology as a factor in society that exerts strong and active influences on individual humans, the organizations we create, and the cultures that emerge.

The Non-Neutrality of Technology

Human bodies are well-adapted to communicate with other humans, but that communication is limited. Successful human communication requires the individuals be close enough to hear or see each other, they share a language, and the message be sufficiently noise-free that it can pass between the individuals. If the spoken message is perceived, then it can enter the recipient's memory, resulting in two copies; one in the sender's brain and one in the recipient's brain. We know through experience and experiment those memories are faulty and fading, which makes communication incomplete and inconsistent.

Humans have created many technologies to mediate communication. Our capacity to use sophisticated language allows humans to encode complex ideas in words, and we have invented many technologies to encode those words in memory systems that are more reliable than the human brain. Prior to writing, these technologies included the repetitive patterns in epic poems, communal call and response songs and tales, and quipas, which were knotted strings used by people living in the Andes Mountains in South America (Wright, 2007). In Western societies, we mark the beginning of print as the dominant information technology from Gutenberg and his press in the middle of the 15th century, but printing presses were in use in Europe and Asia centuries earlier. The electronic digital computers found on students' desks (and in their pockets) are the latest in a long series of devices invented to encode, store, and transport information in a manner more resilient and far-reaching than the human brain and body.

Walter Ong studied the effects of information technologies on societies, and was one of the first to detail the social influences of information technology. Ong (1982) observed "Writing, print, and computers are all ways of technologizing the word. Once the word is technologized, there is no way to criticize what has been done without the aid of the highest technology possible" p. 80); once new technologies emerged, they are used to identify the deficiencies of the previous information technology and judge it adversely compared to the new technology. The conflicts that were noted when comparing Plato's and Hobbes' perceptions of writing as well as the conflicts we see in classroom as teachers struggle to adapt to new technologies are examples of those Ong predicts will be observed when one technology replaces another. He attributed these conflicts to the social and cognitive effects of the new technologies. If the new technology caused no changes, Ong reasoned, there would be no conflict. "Neutral" is the term used to describe things and actions that do not change the state of a system. Because there are changes in human cognition and communication that are associated with information technology, scholars and practitioners refer to the "non-neutrality of technology" to capture the active effects of technology on human interactions.

Not all scholars have recognized the non-neutrality of information technologies, however. For much of the 20th century, the discoveries necessary to design and develop computer and information technologies were made by a group of researchers who perceived technology as a pipeline for accessing information. For these information theorists, the experience of using information was the same regardless of the technology used to deliver it. In his seminal 1945 article "As We May Think," Vannavar Bush, suggested computers were going to improve the efficiency of communication, and he even predicted the invention of the memex (a device that would operate much as the Internet does), but he did not predict any changes in how humans learn with the arrival of digital computers.

More recently, scholars have continued to develop the concept of non-neutrality of technology and they have added to Ong's (1982) observations. The phenomenon can be observed at three levels. The structure and function of individuals' brains are affected by the information technology they experience, especially though their adolescent years. The characteristics of humans' social organizations are affected by information technology; and a society's norms are influenced by the nature of the information technology available.

Effects on People

Brains and the sense organs sending signals into the brains are used by humans to perceive the world and to react and respond to it. Neuroscience researchers are elucidating the nature and details of neural changes when we learn, as well as the details of how memories are recalled. Neuroscience is basic research, so the discoveries are not immediately useful or relevant to educators (Antonenko, van Gog, & Paas, 2014), but discoveries are clearly contributing to educators' understanding of how the environment and its information technology influence developing brains.

Neuroscience has confirmed that the brain is somewhat modular, so different parts of the brain are active when it is processing different types of information (Antonenko, Paas, Grabner, & van Gog, 2010). Since the 1990's, studies have confirmed the dual coding theory (Clark & Paivio, 1991); this theory posits information presented as text and information presented as images is processed in different parts of the brain. There is further evidence that information presented in video format is processed in a third area of the brain (Gerě, & Jaušcvec, 1999). There is evidence that five hours of exposure to information on screens can change the areas in the brain that are used to process information (Small & Vorgan, 2008).

In addition to affecting brain structure and function, the information technology to which one is exposed affects his or her behavior. Those born since about 1990—those who entered school about when the World Wide Web arrived in schools—have been labeled the iGeneration (Rosen, 2010), and those generations have been widely studied by many research groups (Dijk, 2012; Montgomery, 2007; Palfrey & Gasser, 2016; Tapscott, 2009). While each research group attributes slightly different characteristics of these generations to the influences of digital information, there are several observations upon which they seem to concur:

- Individuals in these generations have a proclivity to use digital technology and they consume vast amounts of media.

- These individuals tend to create content and share details of their lives online.

- They are heavy users of social media and they use it to establish and control relationships.

While young people have always consumed large amounts of media (especially recorded music and television), the tendencies to create digital content and share it over social media along with the availability of vast amounts of digital content from other providers is a new aspect of media associated with digital technologies (Rideout, Foehr, & Roberts, 2010). The sharing perceived to be excessive (and disconcerting) by older generations, but natural by the iGenerations, is conflict that can reasonably be interpreted as another example of that which Ong (1982) attributed to the non-neutrality of technology.

It is also clear that individuals in the iGenerations are actively learning when online, and interests and friendships motivate this learning. Indeed, Ito and her colleagues (2010) suggested that youth are developing greater expertise in learning in the digital landscape than adults. For perhaps the first time in human history, there is an information technology skill inversion, as individuals in the younger generations appear to be more skilled than the older generations in using the dominant information technology. This leads Ito (2010) to conclude, "Given the centrality of youth-defined agendas in [interest and friendship-driven learning], the challenge is to build roles for productive adult participation that respect youth expertise, autonomy, and initiative" (pp. 340-1).

Ample research supports the conclusion that brains change depending on the information technology, and research also suggests that humans adapt their behavior to the nature of the information they encounter. Mark Deuze (2006), a media and journalism researcher, concluded digital media demands that we participate in the creation of media as we consume it, that we remediate digital information as we become responsible for navigating and assessing the vast information landscape, and that we discover and invent new and unintended uses of information and technologies through bricolage. In these ways, we live in a media landscape that is much more participatory than the print-dominated landscape of previous generations. We see, as well, that information technology affects both the nature of human brains and the nature of human behaviors.

In her 2017 book, *iGen*, psychologist Jean Twenge attributed the extreme access to digital devices and social networks to a number of trends observed in younger people who were born after 1995. This generation appears to be delaying driving, romantic relationships, and other adult activities compared to previous generations; many report they never attended a party without adults present by the time they graduated from high school. Twenge also attributes greater levels of depression and other concerning mental health trends in this generation to their use of digital devices. She concludes, “The devices they hold in their hands have both extended their childhoods and isolated them from true human interaction” (p. 312).

Effects on Organizations

Humans, we know, are social creatures; the organizations and associations they form are an important part of life in the 21st century. Students leave school to join organizations and businesses after they graduate, and the success of schools is determined by the degree to which graduates are able to function in those organizations. In the same way that individuals in digital landscapes are more active creators and consumers of information than individuals in print landscapes, organizations are becoming more flexible and dynamic in both the internal organizational structures and management practices as well as the nature of interactions with clients and customers.

Olumuyiwa Asaolu (2006), a scholar in industrial and information engineering, applied the label “Fordist (Old)” to organizations that are structured in a manner that reflects industrial technologies. These organizations tend to consume energy to produce standardized products using standardized methods, and they tend to rely on individuals with specialized skills who are managed through hierarchical systems. Asaolu concludes Fordist (Old) organizations are being replaced with those he labels “ICT (New)” which reflect modern information technology. These organizations use information to create customized services through flexible and innovative products. These organizations leverage broad skills held by employees whose work is managed through horizontal structures.

Among the factors contributing to the replacement of Fordist (Old) organizations with ICT (New) organizations is the rapid evolution of IT and the global communication that it supports (Miller, 2011). This creates new problems and new opportunities for organizations, and those that adopt ICT (New) characteristics appear to be abler than Fordist (Old) to adapt to those opportunities that require innovative solutions. The assets and social norms that support innovation are self-creating and self-supporting and they develop organically within ICT (NEW) organizations. Fordist (Old) organizations tend to be highly controlled by the management, but innovative thinking can be neither imposed nor mandated nor can it be standardized, thus Fordist organizations at a disadvantage in situation where flexibility, innovation, and other ICT (New) approaches are necessary.

Manuel Castels, a sociologist who has held positions in both North America and Europe has studied the wide-ranging effects of computer networks on society, especially on economic organizations. Commenting on the role of digital information and computer networks in the rejuvenation of many businesses and industries late in the 20th century, Castells (1996) noted, “Technological innovation and organizational change, focusing on flexibility and adaptability, were absolutely critical in ensuring the speed and efficiency of restructuring” (p. 19). Castels goes on to argue that human cognitive power to process abstract symbols, which is much enhanced by the digital electronic computers, is the basis for our capacity as a species to survive. Further, he posits that while technology is largely shaped by social influences, “the availability of new communication networks and information systems prepared the ground for” (p. 53) new organizations and social structures.

Effects on Society

The effects of information technology on human life extends to society-wide characteristics as well. In preliterate cultures, communication is communal and loud (at least audible). For Plato to teach his students, they needed to be together and to speak and listen. Writing and print allowed communication to be solitary (writers and readers need not be together in time and space) and silent (with practice, reading can be done inside one’s head and writing is largely silent except for our writing tools and our attempts to break writers’ block by talking to ourselves). The manner in which social norms and values are remembered and interpreted in preliterate cultures is dynamic (updated through communal storytelling), and decisions in preliterate cultures are likely to depend on the specific circumstances of a situation rather than on reference to an abstract concept.

Once writing arrives in a society, ideas can be stored in a more permanent manner than they can be in preliterate cultures; abstract ideas enter the culture which allows for money, law and evidence, sacred books and monotheist religions to emerge. Further, those who have greater skill reading and writing tend to have greater political and economic power than those with lesser skills, and children are excluded from much of the information life in a literate society until they become readers and writers. The marginalization of individuals and groups based on lack of communications skill is largely absent from preliterate societies.

In the 20th century, electronic media entered the popular culture in the form of radio, movies, and television. These media again changed the nature of information creation and consumption in society where they were available. Compared to print media, radio and television tended to be consumed in isolation but at the same time (we watched alone, but everyone consumed the broadcast at the same time); this pattern is changing as digital video becomes more popular. While many legal documents are printed, electronic media has come to dominate almost every aspect of economic, political, and social life.

Perhaps the greatest change in information use in societies with digital electronic media compared to earlier electronic media is the degree to which individuals can participate in the global media. With the arrival of the World Wide Web, then web 2.0 technologies that afford users the ability to easily publish content (including multimedia content) to world-wide audiences, the nature of users' interaction with information became more participatory. This access to publishing has contributed to the evolution of many traditional institutions, including journalism. The British Broadcasting Company (BBC), for example, has been active in both encouraging responsible reporting by amateur journalists, and it has developed formal processes for including information from amateur journalists in its reports (Belair-Gagnon, 2016).

Palfrey and Gasser (2016) used the term semiotic democracy to describe the effects of participatory content creation on society. They observed, "any citizen with the skills, time, and access to digital technologies to do so may reinterpret and reshape the stories of the day" (p. 233). Of course, this can threaten social and governmental institutions, and they observed that in times of social and political instability, governments can and do take the step of restricting or preventing citizens from accessing and participating in the technologies that make the semiotic democracy possible. Yochai Benkler (2016), a professor at Yale Law School, observed access to computers and information technology extends throughout society and he claimed, "the change brought about by the networked information environment is deep. It is structural. It goes to the very foundations of how liberal markets and liberal democracies have coevolved for almost two centuries" (p. 1).

Schools for Networked Societies

School as we understand it is not a new invention; for generations, adults have created and sustained them for a wide range of purposes. High schools both provide access to sophisticated and specialized curriculum and keep large numbers of able-bodied individuals out of the work force. Organizational structures and management practices are also articulated to meet a wide range of purposes. Summer breaks allow children to return to agrarian work when it is most needed (even in the 21st century when family farms are largely disappeared from the landscape). In these ways, and many others, we see how schools reflect the societies and cultures that support them. In some instances, the structures and practices remain after the need for them has disappeared. The slow rate of change in schooling is yet another example of the conflict that characterize the time when technologies replace technologies.

For convenience, we can mark the 21st century as the historical moment digital information and information technologies replaced print and ICT (New) organizations replaced Fordist (Old) organizations. Certainly, this is an artificial and blurred boundary, but for our purposes it is illustrative. We can reasonably expect this boundary also marked by a transition in schools; presumably 21st century schools replaced 20th century schools as different skills and knowledge are needed to engage with new information technologies and to participate and succeed in new organizations.

The change to education for ICT(New) organizations and society is not complete. Indeed, as the third decade of the 21st century approaches, there are two clearly different and competing approaches to education we observe. One seeks to preserve and continue education for print and Fordist (Old) organizations and the other seeks to more clearly reflect ICT (New) organizations and to educate for new literacies (Limbu, 2017). Just as writing replaced orality over Plato's protests, we can predict 21st century skills and schools to replace 20th century schools, the nature of schools as the transition continues and after it completes focus this section.

Nominal change in school

In the 21st century, several major political efforts have sought to influence educational policy at a broad level; No Child Left Behind (NCLB) (2002) and the Common Core State Standards (CCSS) (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010) are two that attained national influence in the United States. Advocates for each indicated the effort would revise curriculum, instruction, and assessment for the 21st century. The publishers of tests used as part of CCSS claim they are valid (McCall, 2016), but those claims appear unverified by scholarly research. Further, claims by advocates that constructs and measures used in these efforts are valid and reliable are also unverified by scholarly research. Both NCLB and CCSS appear to be grounded in three assumptions about teaching and learning that dominated in the 20th century but that appear to be unsupported by and even contradicted by the discoveries of learning sciences in recent decades:

- The curriculum (what students should learn) is well-known and accurately reflects the skills and knowledge students need. The reality is that what represents knowledge changes rapidly, and it is impossible to predict exactly which skills or knowledge students is actually necessary for students.

- Educators know with certainty and clarity how to transfer the curriculum into students' minds. Cognitive science is elucidating the details of how humans learn and the environmental factors relevant to learning in ways unavailable to earlier generations of teachers.

- Tests are an accurate and reliable measure of what students have learned. Useful assessments and evaluations of learning will be predictive; performance on those tasks will indicate the student's ability to use the information and skills in other settings. Most tests lack this predictive ability.

Sawyer (2008) referred to education grounded in known curriculum and tests as the Standard Model of teaching and observed it had been widely adopted by the societies with industrialized economies in the 20th century. Ronald Gallimore and Roland Tharp (1992) educational psychologists who studied conditions in classrooms that influence learning, referred to this type of teaching as a recitation script and observed, “the predominant experience of American school children. Sitting silently, students read assigned texts, complete 'ditto' sheets, and take tests. On those rare occasions when they are encouraged to speak, teachers control the topics and participation” (p. 175)

The Standard Model has been increasingly challenged by the observation that innovation economies were replacing industrial economies and the Standard Model is recognized as no longer gave students the opportunities to develop necessary skills. Helen Adabzi (2016), a scholar from the University of Texas at Arlington, observed, “many documents state that the traditional education has failed, and it is time for a new paradigm [that] “teach[es] a combination of basic, new and ‘soft’ skills [to] emphasize critical thinking, communication, and leadership” (p. 256). The Standard Model was also challenged by the observation that other models were more closely aligned with discoveries regarding learning emerging from the cognitive sciences. Deeper learning (Bransford, Brown, and Cocking, 2000) has emerged as a model that recognizes the social and emotional aspects of learning as well as the importance of activity and engagement, including reflection, in learning. Despite the finding that the Standard Model does not result in students developing the skills and knowledge they need for post-industrial economies, Sawyer (2008) noted,

> Many of today’s schools are not teaching the deep knowledge that underlies innovative activity. But it is not just a matter of asking teachers to teach different curriculum, because the structural configurations of the Standard Model make it very hard to create learning environments that result in deeper learning (pp. 48-9.)

It is reasonable to conclude the Standard Model of education is based on assumptions about human learning that have been overturned and it is less effective pedagogy for developing necessary skills than others. Despite this, it seems the Standard Model has been reinforced by the policy determined by NCLB and CCSS.

For many observers (including the taxpayers who fund public schools, the politicians who seek to control schools, the parents who send their children to schools, and even many who work in schools) what constitutes “school” is grounded in their experience with the Standard Model. Their concepts are clear and unquestioned and perceived to be objective and shared by all, so proposals that would produce different experiences for students are often shunned. This factor contributes to “institutional inertia,” and schooling continuing as it has despite evidence it must change.

Also slowing the replacement of the Standard Model is the fact that schools have become highly politicized institutions. In 2006, futurists Alvin Toffler and Heidi Toffler captured the relative speed of change throughout society with this scale: businesses appear to be adopting new information technologies and adapting to them at 100 miles per hour, with other organizations (such as professional organizations and non-governmental organizations) moving almost as quickly; families in the United States are moving at 60 miles per hour. Schools and other bureaucracies are moving at a mere 25 miles per hour. Political parties and legislative processes are moving even slower, at three miles per hour in the Tofflers’ estimate. If we accept this scale, then it is reasonable to assume that schools would be adopting and adapting to new technologies faster than they are if it were not for the slowing caused by political actions (such as No Child Left Behind legislation and the Common Core State Standards initiative) undertaken to “fix schools.”

The inconsistencies between the schools we need for innovation economies and the instruction provided under the Standard Model is yet another example of the conflict that Walter Ong (1982) described when technologies are replaced and that have become familiar in this chapter. Publicly funded and compulsory education for all is widely perceived to be the foundation of economic growth and effective governance in democracies. In the United States, education has become a government service influenced by increasingly centralized authorities as the population grew and become more urbanized and mobile (McCluskey, 2007). Especially since 1983 and the publication of *A Nation at Risk* (The National Commission on Excellence in Education, 1983), education has become an issue in national elections at a level that was not observed previously. This has placed education firmly among the institutions that innovate at the slowest rate.

Alternatives to the Standard Model

Many educational scholars and practitioners have recognized the inadequacy of the Standard Model in recent decades and they have proposed alternative models of education. The (incomplete) list of alternatives includes authentic learning (Herrington, Reeves, & Oliver, 2015), natural learning (Caine & Caine, 2011), project-based learning (Krajcik & Shin, 2014), problem-based learning (Lu, Bridges, & Hmelo-Silver, 2014), complex learning (Kirschner, Jeroen, & van Merrienboer, 2008), learner-centered instruction (Stefaniak, 2015), situated learning (Lave & Wenger, 1991), and cognitive apprenticeships (Dennen & Burner, 2008). While advocates for these different methods vary in the specifics of how they would implement schooling, there are several assumptions about teaching, learning, and testing that they share and that differentiate these approaches from the Standard Model of schooling:

- The curriculum is assumed to be more dynamic and vastly greater than can be articulated in standards and "covered" by lectures and similar instruction, so these methods tend to include an increased role for activities in which students learn how to learn. It is reasoned that students who gain experience learning with independence are better prepared for rapidly changing and unpredictable knowledge and situations that characterize New (ICT) organizations and digital cultures.

- Because the curriculum will vary and because their curriculum will, in part, be self-defined, teachers cannot accurately predict students' paths through the curriculum. Further, new discoveries are likely to invalidate some of the extant curriculum before it can be completed. For these reasons, what students learn may vary.

- In these models, learning is understood to be a social activity as much as it is a cognitive activity. Meaningful social engagement between students and teachers and other experts and among students are purposefully designed into the learning activities.

- How learning is demonstrated varies. In these models, learning is best demonstrated through performance on authentic projects and performances, while schools based in the Standard Model tend to rely on test scores as the primary measure of learning.

- Finally, metacognition—knowing how and what one knows—is a goal of learning in the alternatives to the Standard Model.

The boundaries between schooling when the Standard Model dominated and 21st century schools are not as clear as I have presented. Activities, lessons, courses, and curriculum frameworks that promote 21st century skills have been available for decades (Dede, 2010). Student-based learning, constructivist methods, and other alternatives to the Standard Model of teaching have been described and promoted by scholars and practitioners, but those methods have largely been marginalized and have not been the focus of the wide-scale efforts to define educational policy. It is anticipated that 21st century pedagogies will replace the Standard Model, and the Standard Model will become the marginalized pedagogy.

Daniel Pink (2006) can be credited with popularizing the term "necessary, but not sufficient" to describe the linear skills that are well-developed through the Standard Model. Scholars have continued to elucidate many trends, especially economic trends, that necessitate the curriculum be revised to both provide linear skills, but also prepare students to be flexible and innovative. The nature of the workers needed in institutions that reflect the ICT (New) organization, illustrate these changes. Johannessen (2008) concluded,

> the workforce will shift away from employees who have traditional, practical training backgrounds and towards an ever-increasing number of employees who have had a higher education and are theoretically well equipped. Such workers will be capable of working in a problem definition and problem-oriented manner and possess skills for both analysis and synthesis (p. 407).

Richard Suskind and Daniel Suskind (2015), scholars and policy analysts from the United Kingdom, observed workers "will need to learn to communicate differently, to gain mastery of the data in their disciplines, to establish working relationships with their machines, and to diversify" (p. 114). The factors contributing to the changing nature of educational outcomes include globalism and technology-driven automation, as well as the availability of increasingly sophisticated information technology. Levy and Murname (2004) cited evidence that there are four trends that are changing that nature the tasks that will be necessary for workers: (see figure 1.1):

- Complex communication, which requires one to interpret sophisticated information and articulate clear explanations, is becoming one of the most important skills for workers.

- Expert thinking, which requires one create solutions to unique and unfamiliar problems, is becoming increasingly important (but less than complex communication).

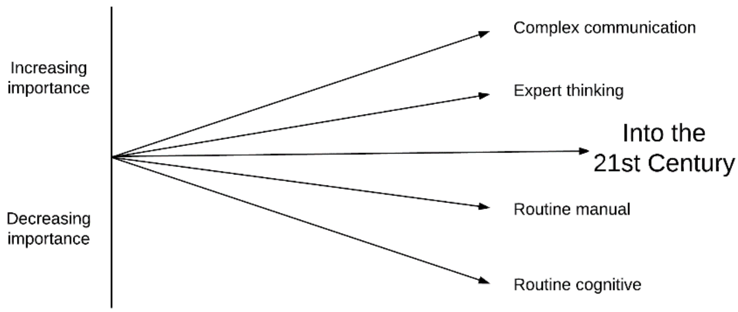

Figure 1.1. Expected trends in 21st century work (Adapted from Levy and Murname, 2004)

- Routine manual labor is decreasing in importance as robots and other tools automate the easy-to-repeat physical tasks common in the industrial economy.

- Routine cognitive work is decreasing even more in importance as algorithms perform simple analyses and

> restatement of information, and draw conclusions based on quantitative data.

While most see clear connections between the skills Levy and Murname identify and the curriculum common in the Standard Model, there is also increasing need to diversify the skills that students develop during their school careers; these emerging skills are motivated by factors other than economic as well. In his 2010 book *Wisdom*, Stephen Hall who is an award-winning writer about science and society, posed the question, "How do we make complex, complicated decisions and life choices, and what makes some of these choices so clearly wise that we all intuitively recognize them as a moment, however brief, of human wisdom?" (p. 6). Hall recounted the story of a scholar who has become a leader in the field of wisdom studies, and who concluded,

> that wisdom represented a state of mind beyond standard metrics of intelligence, and this revelation forced him to see inherent failures in the educational system, and the philosophy of educational testing, and the degree to which too narrow measures like IQ tests fail miserably to predict lifetime satisfaction (p. 245).

Hall concluded wisdom is grounded in eight characteristics which are generally ignored in the Standard Model, but that are more important than traditional measures of knowledge when solving complex problems: emotional regulation, knowing what's important, moral reasoning, compassion, humility, altruism, patience, dealing with uncertainty.

While advocates for the Common Core State Standards and other standards argue that curriculum is known and measurable via a test, the scholars whose work is summarized in this section do not appear to agree. They appear to concur, rather, with Douglas Thomas and John Seely Brown who concluded full participation in the digital society necessitates individuals have the capacity for lifelong learning as workers and citizens will be adapting to new technologies and new information in perpetuity. They propose schooling be focused by, "a new culture of learning the point [of which] is to embrace what we don't know, come up with better questions about it, and continue asking those questions in order to learn more about it" (Thomas and Brown, 2011, p. 38).

Clearly, schools must adopt curriculum and instruction to reflect the needs of citizens in the digital society, and there have been localized efforts to make these changes. The rate at which schools are changing appears to be far behind the speed at which other organizations are changing, but schools are adapting faster than the political organizations that govern schools. The design of the learning environments necessitated by a world in which traditional skills and knowledge are still important, but that are no longer sufficient has important implications for IT managers as both of these models of teaching are dependent on IT that is appropriately and properly configured.

Implications for IT Management

It was concluded in the previous section that the Standard Model is being replaced, however, it is anticipated that both the Standard Model and its alternatives will organize teaching and learning into the future. It follows that IT managers will be responsible to ensure that the systems they create and sustain have the capacity and functionality to support both types of teaching and learning.

The Standard Model of education is dominated by instructionism in which an expert (the teacher) defines the content to be studied, the manner and order in which it is going to be experienced, and finally determines the extent to which each student has learned it. While some associate instructionism with the leaners being passive recipients of information, Burton, Moore, and Magliaro (2004) suggested instruction can provide a structure for approaching a complex body of knowledge and also for maintaining knowledge. Reif (2008) identified several factors that make instruction effective including articulating very clear goals; the inclusion of explicit and implicit guidance, support, and feedback that can be individualized; and providing timely and appropriate feedback.

Instruction is amenable to deconstruction into several components: goals, a predictable path through known content, and clear determination of outcomes, along with appropriate feedback. These are all clearly definable and knowable before the instruction begins, thus instruction amenable to technology-based delivery.

Reif (2008) concluded, "Computers are well suited for instructional purposes because they provide a dynamic medium that can not only convey information in visual and auditory forms, but can also flexibly interact with users so as to respond to their actions" (p. 428). Instructionism has been used to create a variety of digital educational materials. This list includes arcade-style games designed to teach mathematics skills, spelling words, typing skills, and similar lessons; intelligent tutoring systems for individualized lessons (e.g. test preparation systems); and simulations, which are designed to make the instructional activity more context-rich than arcade-style games typically are. Bowers (1988) criticized these designs as "students encounter a one-dimensional world of objective data" (p. 34), and he concluded the prejudices and biases of the programmers exert strong and perhaps unintentional effects on the lessons learned. When they are aware of these limitations and take steps to minimize their influence on the materials, instructional designers can create very effective instructional materials (for appropriate purposes) by the judicious application of technologies.

Efficacious IT managers will build systems that can be used to deliver instruction by ensuring:

- Students can access appropriate instructional materials including both locally installed programs and web-based media;
- Teachers have resources for creating instructional materials;
- Instructional materials are accessible to those students who have disabilities;
- Teachers have access to easy-to-use systems for managing instructional resources they create and that they find. This can include both local copies of files and online repositories.

One of the reports that emerged from the comprehensive John D. and Catherine T. MacArthur Foundation's Digital Media project was *The Future of Learning Institutions in a Digital Age* (Davidson & Goldberg, 2009). In that book, 10 characteristics of learning in the digital age are proposed (see table 1.1). The authors observed, "Digital technologies increasingly enable and encourage social networking and interactive, collaborative engagements, including those implicating and impacting learning" (Davidson & Goldberg, 2009, p. 24). They further confirm a commitment to developing alternatives to the Standard Model of education noting learners will become more participatory in virtual environments "where they share ideas, comment on one another's projects, and plan, design, implement, advance, or simply discuss their practices, goals or ideas together" (p. 12). As the pillars are more completely implemented in a community, the implications for teaching and learning as well as professional learning become more pressing.

Table 1.1. Pillars of Digital Learning (adapted from Davidson & Goldberg, 2009)

Pillar	Implications for School IT
Self-directed learning	Access to rich materials through flexible and diverse media venues
Horizontal structures	Systems allow for new connections and emerging networks for users
Collective credibility	Ensure ubiquitous access to information
De-centered pedagogy	Learning participate in communities beyond the teacher-dominated local one
Networked learning	IT facilitates both internal and external interaction
Open source education	Materials come from many sources
Learning as connectivity and interactivity	IT enables participation in professional activity
Lifelong learning	Learners select and use appropriate tools
Mobilized learning	Rules and compliance are replaced with outcomes and flexibility
Flexible scalability	Interaction is both local and global

In the milieu of researchers' and practitioners' perceptions of the trends emerging in digital education, there is evidence to support Gros' (2016) observation, "The ubiquity of technology calls for a shift away from low-level use of technology, such as drilling, practice and looking up information. Rather, smart education encourages 'high-level' uses of technology, utilising it as a 'mind tool' or 'intellectual partner' for creativity, collaboration, and multimedia productivity" (p. 6). Such systems are built for interoperability and seamless connection of devices (to facilitate use of multiple devices), allow for adaptable configuration for users' preferences, and engage teachers and learners in natural engagement (Zhu, Hu, & Riezebos , 2016).

To address the pillars of digital learning, efficacious IT managers in schools will revise how the range of IT infrastructure, practices, and policies are instantiated. The tools must accommodate interaction and creation of information as much as it accommodates access to and consumption of information. The teaching and learning that students experience will likewise be flexible and interactive in a manner it was not when the Standard Model dominated. The design of these learning environments necessitates insightful and attentive school leaders as well.

Conclusion

Given the conflict that accompanies the arrival of new information technologies, it is reasonable to expect scholars and practitioners to have struggled to define the appropriate role for the devices in teaching and learning in today's schools. Some have adopted a stance similar to that Plato adopted towards writing; they have avoided it entirely. Others are quick to adopt every new innovation. Between those extremes we find the more reasoned observers and practitioners who advocate for purposeful and thoughtful approaches to using information technology in classrooms. Todd Oppenheimer (2003) who generally argues for avoiding technology in his book *The Flickering Mind* observed computers "can be effective when they are used only as needed, when students are at the right age or them, and when they are kept in their place" (p. 394). David Jonassen, a scholar who studied educational technology for decades and was recognized as a leader in the field, differentiated active learning in which technology is used to “engage learners, in representing, manipulating, and reflecting on what they know,” from passive learning in which students used technology for “reproducing what someone tells them” (2000, p. 10).

We know schools are designed for the purpose of enabling and encouraging young people to fully engage with information technology so they can participate in the economic, political, and cultural life of society. The curriculum comprises those skills and that knowledge that is necessary for this goal. It is expected the complexity of society’s IT will be reflected in the strategic goals articulated by school leaders and the curriculum and instruction designed to achieve those goals. For the digital generations, the process of revising curriculum and instruction is further complicated by the changing nature of information technology in the society. Plato, we saw previously, argued against the incorporation of reading and writing into schools.

One’s perception of changing information technology depends on the direction from which one perceives the change. Older generations grew up using the information technology that is being replaced tend to perceive the arrival of IT and the transition in schooling associated with the IT in a negative manner. For them, using new information technology is degrading human cognition and students are not being taught the skills and knowledge that they value and that were necessary for their generation. Younger generations perceive the emerging information technology as natural to their future, and they tend to adopt the technologies and become comfortable with emerging information and technologies. The challenge for efficacious IT managers is to negotiate the many factors that affect the transition.

Chapter 2: Technology-Rich Teaching & Learning

The transition from the Standard Model of education to the alternatives that are emerging to replace it is an incomplete and unpredictable activity. IT managers (along with the teachers they support) who have a framework for understanding the role of technology in the many activities that comprise teaching and learning will design more effective systems than those who do not. In this chapter, technology-rich teaching and learning is deconstructed so it can be understood by IT managers.

Because new information technologies (including hardware, software, and information sources, along with new uses of each) emerge very quickly compared to the periodicity of schools (new technologies appear several times during a typical school year), teachers must adopt and adapt to them constantly. When deciding which technologies to use, teachers are more likely to use technologies that:

- Are easier to use than existing technologies;
- Are more effective than existing technologies;
- Complement existing technologies.

While it may appear easy to select technology that meets these characteristics, those decisions are complicated by the diversity of the devices that emerge as well as the effects the technologies have on students and teachers and culture. In this chapter, a framework with which educators can understand the role of new technologies in their work is described. In addition, strategies for supporting educators' understanding of technologies in their classrooms are described.

Logistic Goal

A comprehensive IT management plan will articulate a logistic goal related to supporting teachers as they become competent users of IT and teachers with IT. In addition to capturing a central role for information technology in the curriculum, this logistic goal will include all students and will include diverse technology experiences. For example, "Every student will gain experience using technology to access, consume, and create information and to interact with others in all classes."

Context for the Logistic Goal

The need to articulate a logistic goal supporting technology-rich teaching and learning for all students, and in all areas, arises from the non-neutrality of IT. The information technology common in a society determines what it means to be "literate" in the society, so all teachers have the responsibility to expose students to technology-rich information and interaction in their field. Teachers who ignore IT today are no different from teachers who ignored text in previous generations. We know from the arguments in Chapter 1 that information technology affects individual humans, the organizations humans create, and the culture in which humans live. These effects extend into classrooms as well. To accomplish the logistic goal of using technology in classroms, school IT managers support a) on-going training to use IT, b) learning about emerging information technologies, and c) design opportunities to ensure IT-rich teaching and learning is embedded in all curriculum areas.

Soon after desktop computers arrived in schools, the Apple Classrooms of Tomorrow project studied the interactions of students and teachers in classrooms. One of the findings from that work, and a finding that has been demonstrated ever since, is that putting new information technology in classrooms does not mean it will be used for effective teaching and learning (Sandholtz, Ringstaff, & Dwyer, 1997; Schofield, 1995). In the decades since computers arrived, there has been on-going study of the factors that influence teachers' use of technology. It is clear from this research that teachers' beliefs about technology and teaching, the nature of the technology and its support, other's use of technology, and the availability of curriculum and materials that make of use technology are all important factors affecting the decision to use computers in a classroom (for example (Buabeng-Andoh, 2012; Kim & Reeves, 2007; Mumtaz, 2000; Somekh, 2008; Zhao & Frank, 2003). Even as researchers understood the factors associated with technology use by teachers and the affordance of IT associated with alternative methods, the Standard Model of instruction dominated and technology continued to be a marginal part of students' experience.

For the most recent generation of teachers, the difficulties of finding a role for technology in the classroom and then fully implementing it has been complicated by three factors. First, the rate at which computers and information technology change has been rapid and accelerating. New technologies emerge and gain wide-spread acceptance in very short time spans compared to technologies throughout the 20th century. For educators, whose technology-rich teaching tends to be cyclic with a one-year period, the obsolescence of technologies that happens on a time scale of months can be disconcerting and disruptive.

Second, the current generation of educators are working at a time when cognitive and learning sciences are challenging much of what they experienced as "good" education when they were students or what they were taught in their teacher education programs. We are understanding the complexities of human brains and the important role that emotions and social interaction play in human learning, so educators can no longer simply be dispensers of information. Creating effective learning environments is more complicated than it was previously regardless of the role of technology.

Third, education has become politicized at a scale that it was not in earlier generations. In the United States, education law and policy is created at all levels of government, and these laws can sometimes be contrary to other laws and they often are contrary to what cognitive and learning science tells us is natural for humans. In educational technology, the United States government has written technology plans in which educational and political leaders articulated new and more sophisticated expectations for teachers and school IT managers:

- *Getting America's Students Ready for the 21st Century: Meeting the Technology Challenge* (1996)—The first technology plan focused on ensuring teachers had computers and software and were trained in how to use them; this plan largely addressed the need to obtain computing devices and ensure teachers could operate them.

- *e-Learning: Putting a World-Class Education at the Fingertips of All Children. The National Educational Technology Plan.* (2000)—This plan continued the focus on hardware, software, and also extended infrastructure to include networks and extended the focus teachers' learning to the transformation of instructional activities to make use of technology.

- *Toward A New Golden Age in American Education***—***How the Internet, the Law and Today's Students Are Revolutionizing Expectations (2004*)—This plan changed the focus from technology planning to different types of technology-rich learning, namely online learning.

- *Transforming American Education: Learning Powered by Technology.* (2010)—This technology plan again refocused technology planning on assessment and measuring student outcomes.

- *Future Ready Learning: Reimagining the Role of Technology in Education. National Education Technology Plan* (2016)—This plan is comprehensive and includes goals related to infrastructure, teaching and learning, professional development, innovation and assessment.

- *Reimagining the Role of Technology in Education* (2017)—In this plan that Department of Education of the United States intends to begin more frequent and less comprehensive updates.

In the decades-long history of advice for IT managers from the national education leaders, we can see changes in what they were expected to do locally. While it is reasonable for all organizational leaders, especially leaders of public institutions, to adjust their goals and their planning efforts to reflect new knowledge and developing practice, the changes in direction coming from external and politically powerful influences can produce unintended consequences for local communities. What was “best practice” while one plan was in place is abandoned when a new plan is released. Planners are rarely able to follow through with steps to address one set of goals before the next necessitates they turn their attention to other goals. The result is that educational technology planners have rarely been able to complete their plans and fully understand the implications of their work before the focus changed.

Educators are also a non-neutral part of schools; their beliefs, values, and experiences all affect the actions they take. For those who have become deeply engaged with a set of practices and who have invested much cognitive effort in understanding the rationale behind those practices, the decision to abandon them can be distressing. This problem is exacerbated when the decision-makers show little empathy for the knowledge of the teachers and the affective connection they have for their work.

To accommodate these many changing factors influencing IT managers and the environments for which they design systems and to introduce some consistency into the planning for technology-rich teaching and learning, IT managers can use theory to organize their efforts. When work is organized by sound theory, changes in the focus of technology planning can appear less drastic to members of the organization than when new goals cause new priorities. This is particularly effective when they seek to define improvement in ways that can be affected by known factors and that can be observed with known methods.

Deconstructing Technology-Rich Teaching

Teacher education has traditionally been informed by a framework comprising the content dimension (what is to be taught or the curriculum) and the pedagogy dimension (how it is taught or instruction). Shulman (1987) suggested teachers’ content knowledge and pedagogical knowledge cannot be developed in isolation, so he proposed “pedagogical content knowledge” (PCK) to describe the capacity of a teacher to organize, explain, and communicate ideas so that students understand the content. The adage commonly applied to education, “you never really understand it until you teach it,” captures the interconnected nature of content and pedagogy; educators better understand content through teaching it and they better understand pedagogy by applying it to teaching problems in their classrooms.

In extending Shulman's concept of PCK, Mishra and Koehler (2006) observed technology had emerged as a distinct type of knowledge. In adding technological knowledge (TK) to Shulman's model, Mishra and Koehler recognized computer technology is qualitatively different from pencils and paper and the other long-established print technologies, so it enters the model as a separate type of knowledge. It is reasoned that as digital information technology becomes more familiar, its existence as a separate type of knowledge will decrease. Technological pedagogical content knowledge (TPCK) (see figure 2.1) has become a very useful framework for understanding teaching and learning in the technology-rich school. While TPCK does comprise distinct and isolatable types of knowledge, it is presented as a model that "emphasizes the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology," and "emphasizes the interplay of these three bodies of knowledge." (Mishra & Kohler, 2006, p. 125).

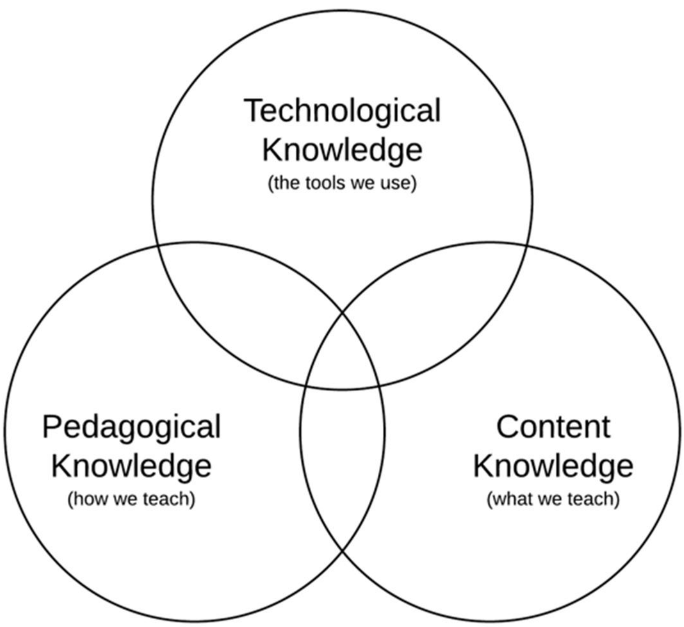

Figure 2.1. TPCK model (adapted from Mishra & Koehler, 2006)

As a framework useful to inform IT management decisions in school, TPCK identifies seven types of knowledge that can be improved with educators' increased awareness of new technologies and with their increased knowledge of teaching methods that make use of technology. The state of TPCK within a school community can evaluated from an individual's perspective and also from the perspective of the entire faculty. Social influences are known to be an important determinate in technology acceptance (Venktah & et al. 2003), so each individual's TPCK is affected by the group's TPCK, and the TPCK of influential individuals are particularly important in affecting the group's TPCK.

TPCK is proposed as a dynamic framework and Mishra and Kohler (2006) anticipated it would change over time. Shulman (1987) did not differentiate books, pencils, paper, and other information technologies into a separate type of knowledge when PCK was first elucidated; he reasoned those were transparent technologies and a stable part of teaching and learning for generations, thus no specific knowledge was necessary to use technology. Given the continued rapid development and diffusion of information and computer technology hardware, software, and network platforms, technological knowledge is anticipated to be an important part of TPCK into the foreseeable future. Further, the nature of the classroom determines how TPCK is defined and instantiated. Mishra and Koehler (2006) observed, "there is no single technological solution that applies to every teacher, every course, or every view of teaching" (p. 1029).

Using TPCK, IT managers can identify and support all aspects of technology in teaching and learning. The model also allows IT managers to identify and clarify the connections between the various types of knowledge. In addition, TPCK facilitates understanding of who must be involved with decisions and who must lead and participate in training, curriculum development, and other professional development activities.

Technological Knowledge

When desktop computers first arrived in schools, leaders found it necessary to provide training and support in the basic operation of the devices. At that time, teachers were unlikely to have access to computers at home and it was unlikely they had been exposed to them during their professional preparation. (In the mid-1980's, I was in the minority of my peers enrolled in the teacher education program at out state university who enrolled in the optional "Computers in the Classroom" course offered to undergraduate students; most of my colleagues earned their teaching credentials without any formal experiences with computers.) Simply turning computers on and loading software was the focus of the first computer training for teachers. Software tools such as word processors and spreadsheets were also new, so training sessions introduced educators to the steps of creating, editing, and managing files as well. This reality is also reflected in the goal articulated in the first National Education Technology Plan for the United States which was written in 1996. At the time, educational policy makers sought to address the Technology Literacy Challenge which President Clinton had defined as connecting every classroom to the Internet and ensuring teachers could use it.

In the decades since computers arrived, they have become common household tools and their use is deeply embedded in the higher education courses that are needed to be qualified for almost any position in education. In those same decades, very complex software and network services have been adopted by schools to manage information and provide interaction for educational and business purposes. The result is that educators' technological knowledge includes that which they must develop and maintain on their own and that which must be developed by IT managers. Part of the screening process for candidates for licensed educators and unlicensed assistants who work directly with students must ensure each who fills one of those positions is capable of operating a computer and common software for professional purposes. Educational professionals arrive at their positions with these skills and maintain them with minimal training throughout their careers. Powering a computer on, logging on to networks, and creating and managing files using locally installed software and cloud-based productivity suites are all tasks educators must be able to accomplish with efficiency, confidence, and independence. In addition, they should be capable of searching and finding credible information on the Internet; this includes multimedia information as well as electronic versions of printed materials. Further, educators should model responsible and ethical use of technology systems and digital media. Finally, educators should be able to adapt to new versions of software and similar upgrades quickly and with little direct instruction.

There are some tools educators should not be expected to use without direct instruction and IT managers must plan for these needs when newly hired educators are "on-boarded" and to support educators during major transitions. The IT systems that require direct instruction include:

- Procedures and credentials for logging on to all systems that are needed by the professional, including local area network, email, and all web services used to manage employment, data, and instruction;

- Instructions for managing rosters and grades through the student information system; these systems are notorious for being "not user friendly," which can be attributed to the differences between the vocabulary and structures used by designers and programmers and the language and methods used by educators;

- Instructions for posting to the educators' page(s) on the school web site, the learning management system, social media sites, and other systems for sharing information with both internal and external audiences they are expected to use.

Implicit in this as well is the expectation that educators will be introduced to local policies and procedures relative to acceptable use, procedures to report malfunctioning IT systems, scheduling shared resources, accessing printers, and similar details related to individuals' use of the specific IT systems installed in the school. On-boarding procedures for new staff must address these aspects of using IT, and changes in how these systems are configured necessitates training for all faculty and staff to ensure efficient and effective use of the new tools.

Content Knowledge

Content knowledge may appear to be the most clearly understood and defined type of knowledge. We all expect, for example, chemistry teachers to understand the concepts, idea, and procedures of chemistry; and this content is found in chemistry textbooks. By successfully completing advanced undergraduate courses in a content area, teacher candidates demonstrate sufficient content knowledge so they understand what they are supposed to teach, including relevant details such as how to recognize when chemistry is being done in an unsafe manner.

The content that future teachers study in their undergraduate courses is developed by those with advanced degrees in the field. Their expertise is assured by the universities granting their degrees, their research, participation in professional organizations, and service to the universities where they are employed. The reality of content knowledge for many educators is becoming more complicated in the digital world, however. Two factors appear to be exerting particularly strong effects on content knowledge as it is experienced in schools.

First, digital technology makes sophisticated information far more accessible than it was in the print-dominated world. For many generations, access to information written by and for professional chemists (for example) depended on access to a research library where the copies of the journals were stored and the professionals who taught at that university could help individuals access and understand that information. Since computer networks have become widely available, access to professional literature (which is now digital) has expanded to every location with an Internet connection and a subscription to a database of periodicals is located.

Second, digital information tools are used by individuals, including those with dubious credibility, to distribute information widely. Further, information has become politicized to a greater degree than it was for previous generations, and marginalized and fringe ideas and interpretations of evidence are becoming widely reported and defended.

Together, these factors both afford new opportunities for students and teachers and cause difficulties for those people. Both the affordances and difficulties have implication for efficacious IT managers. These are also the foundation for the pillars of digital learning (Davidson & Goldberg, 2009) (see Table 1.1).

In 1644, John Milton composed a pamphlet in which he argues for freedom of expression; areopagitica has been adopted as a term to describe the capacity for individual to compose and distribute any ideas they see fit. Digital tools, especially those called Web 2.0 tools have been interpreted as the realization of areopagetica and students can use these tools to extend and expand the audience of their works. They no longer create solely for their teachers, but they can create for global audiences. This changes the nature of writing and creating for students.

Areopagetica has been adopted by other creators as well, so the vast content available to educators and students includes accurate information from credible sources, fiction packaged as fact, as well as myths, misinterpretations, sarcasm presented as fact. These many variations fill the space between accurate and credible information and purse falsehood. This disparate information led Mark Dueze (2006), a scholar of media and journalism, to conclude the digital media landscape is filled with content creators who "juxtapose, challenge, or even subvert the mainstream" (p. 68) for a variety of reasons.

In a 2016 report on science communication, the National Academies noted a study in which 40% of Americans reported they get science news from Facebook. This contributed to the Committee on the Science of Science and Science Communication (2016) to observe,

> there are more actors in the media landscape who may, either intentionally or unintentionally, provide inaccurate science information. While today's science media landscape is likely larger than the declining mass media/newspaper-delivery system of the past, it does not offer clear mechanisms for filtering out false, sensational, and misleading information. More than ever before, citizens are left to their own devices as they struggle to determine whom to trust and what to believe about science-related controversies (p. 4-2).

In the months after the 2016 elections in the United States, the term "fake news" gained in popularity to describe the phenomenon of unverified information in the media. For K-12 educators, navigating and helping students to navigate this emerging information landscape determines the reality of content knowledge.

An increasing number of organizations are influencing the contents of recommended curriculum and resources, and this is further complicating content knowledge (CK) for educators. In recent decades, educators' professional organizations have begun publishing curriculum standards (for example National Council of Teachers of English & International Reading Association, 1996; National Council of Teachers of Mathematics, 2000; NGSS Lead States, 2013). In the 2010, the National Governors Association, initiated the Common Core State Standards, which is an effort to create a national curriculum in the United States. Ostensibly these organizations seek to improve education, but the political nature of governorships makes this a dubious claim; further, educators professional organizations may be motivated to maintain and expand membership rather than affect education.

Textbook publishers also exert strong influences on what is taught. In some jurisdictions, a small number of textbooks are adopted for use by large number of students, publishers approach these areas as mass markets and adopt the strategy of providing the least objectionable content (Johnson, 2006) which allows publishers to sell to the widest audiences with the least potential for offending or alienating large subpopulations so that their media is avoided.

The open educational resource (OER) movement is another factor that is affecting content knowledge in the 21st century school. OER's are alternatives to textbooks that are published under copyright licenses that allow others to copy, edit, and redistribute the materials without the need to pay the original author or to seek further permission. Typically, an open education resource originates when an expert (often one who teaches undergraduate courses in a field), polishes and details the resources prepared for his or her students, and uploads them to the Internet under the Creative Commons license. An educator who finds the resources and wants to adopt them will download the file, edit it to meet his or her students' needs, and the focus of the course being taught. The materials derived from an OER source are then made available to the students, and to complete the transaction, the derivative resource is contributed back to the open education community.

Educators and efficacious IT managers are left with the task of providing appropriate access to the vast information sources that are available so they can maintain and update their content knowledge. They provide access to full-text databases for library patrons, they help teachers learn about and design learning activities that give students experience navigating the vast information landscape, and they support educators who participate in OER communities all the while seeking to minimize access to information of dubious credibility.

Pedagogical Knowledge

Of the three individual types of knowledge that contribute to TPCK, pedagogical knowledge is perhaps the most complicated as it is the one with the broadest definition. Relevant technological knowledge is largely defined by the systems available in the school; content knowledge is largely defined by experts who teach the teachers and by textbook and OER publishers. Technological knowledge and content knowledge are clearly bounded and consensus can generally be reached about what constitutes the domain and how it can be improved. Pedagogical knowledge, on the other hand, is defined differently by different scholars and vastly different actions can be called pedagogy. Further, the appropriate pedagogy depends on the goals of the activity as well as the nature of the students and the nature of the curriculum. Pedagogical knowledge is a less clearly understood than other types of knowledge and consensus regarding improvement cannot be easily reached.

How pedagogical knowledge is instantiated in the classroom is largely dependent on decisions made by the teacher. Much of the professional discourse on pedagogy, including research and both pre-service and in-service teacher education, differentiates two types of pedagogy. The Standard Model captures one approach to teaching that continues to be supported by various stakeholders. Chris Dede (2010), a scholar from Harvard University, reviewed the many curriculum frameworks that had been produced in the 21st century, and he concluded they demonstrated that educators and education leaders were "systematically examin[ing] all the tacit beliefs and assumptions about schooling that are legacies from the 20th century and the industrial age" (p. 73).

In recent decades, a number of pedagogical models have been presented that call for students to play a more active role in defining curriculum building knowledge, and communicating what they have learned than it typically allowed in instructional pedagogies. While advocates for these many methods differ in the specific details of classroom activity, these methods share the common elements of a curriculum based in complex problems, ample opportunities for social interaction (between teachers and students and among students), students are found articulating their new knowledge, and attending to metacognitive understanding. Advocates for these methods ground their pedagogy in cognitive psychology (rather than behaviorist psychology) and build their rationale around theorists such as Jean Piaget, John Dewey, and Lev Vygotsky.

Instructionism, which is largely used in the Standard Model, is teacher-centered pedagogy, and it has been established that it can be applied with efficacy to the small portion of content that consists of well-known concepts and ideas as well as procedures that can be clearly described. When teachers use instruction, they plan the logical path through the content and they decide when students (either individually or collectively move along). Teachers also measure success by students' retention of the information and procedures. These methods are grounded in the assumption that learners respond to rewards and punishments; it is reasoned that by rewarding answers and actions that are aligned with expectations (or by punishing those that are not), teachers can promote learning.

Pedagogical knowledge extends beyond understanding the nature of teaching strategies and skill at using those strategies to plan and execute lessons. Educators can approach their work from different perspectives and this affects both what they plan for students and how they present lessons. Douglas Thomas and John Seely Brown differentiate education that teaches *about* content from education that teaches *within* the content. When students learn about a subject, they are external to the content and teaching focuses on transferring declarative knowledge and procedures to the learners. Thomas and Brown (2011) suggested this can be mechanistic with "learning treated as a series of steps to be mastered…." (p. 25). When students learn from within the subject, they adopt the methods and approaches of those who work to investigate problems in the field and they produce products similar to those created by workers in the field. This leads to learners developing both explicit knowledge and tacit knowledge, and Thomas and Brown (2011) observed, "the point is to embrace what we don't know, and continue asking those questions in order to learn more and more…." (p. 38).

Research focusing on learning in informal situations (Lemke, Lecusay, Cole, & Michalchik, 2015) is extending pedagogical knowledge to recognize the role of the learners in the process. Rogoff (1990) described guided participation as a method of informal learning that started with highly-scaffolded modeling and demonstration by mentors early in the experience, but learners assume increasing responsibility for planning, undertaking, and judging the learning products as they develop greater expertise. Caine and Caine (2011) proposed guided experience as a pedagogy that captures the nature of learning that occurs in natural environments, which follows the perception/ action cycle. The perception/ action cycle posits learning is the continuous process of recognizing a situation, interpreting it according to what it is already known, acting, and then adjusting further perceptions according to feedback after acting. Guided experiences are based on three elements:

- *Relaxed alertness* which find the learners motivated and prepared to learn in a stress-free, but high-expectation, environment.

- A *complex experience* which finds the learners acting in the same manner as experts rather than learning about what experts know.

- *Active processing* experience which finds the learners thinking about and making sense of their experiences.

Digital media is also presented as more amenable to guided experience than print. Caine and Caine (2011) even suggest that “technology often plays havoc” with pedagogy designed to transmit knowledge as it “includes student decision making, applying creative solutions to complex and real-life problems, and negotiating with peers and experts” (p. 20). Because more channels of communication, including body language and other movements, are possible with video but nit with text, the nature of the learning that can occur is different when using video media.

Mizuko Ito and her colleagues at the Digital Media and Learning Research Hub seem to have expanded the definition of natural learning as they studied connected learning in young people who comprise the digital generations. That research group observed learning that occurs outside of school tends to be “socially embedded, interest-driven, and organized toward educational, economic, or political opportunity” (Ito, et. al, 2013, p. 6). The students who arrive in today’s classrooms are active and independent learners because of their experiences in the digital world, thus their experiences influence which pedagogies are effective with these populations. Such differences have been recognized by educational scholars for decades, and they led Bereiter (2002) to conclude, “everyday cognition makes more sense if we abandon the idea of a mind operating on stored mental content and replace it with the idea of a mind continually and automatically responding to the world” (pp. 196-7).

As students become more active in creating and communicating new knowledge, basic skills and knowledge can become relevant, so students become motivated to learn the content that is teachable through instruction. As they adopt student-centered methods, many educators are finding a renewed need to include instruction-based methods in their classrooms. This need is less predictable than in instruction and tends to hold the attention of individuals or small groups of students; computer technology and digital media are meeting those needs. Consider the science student who is investigating trajectories of projectiles; she will find it necessary to work with quadratic equations. Using technology, the teacher can direct the student to a lesson reviewing the methods of solving quadratic equations. There is evidence such lessons that include worked examples in which the steps are explicated can be very effective strategies of instruction (Shen & Tsai, 2009). These video lessons can be made available in a learning management system so that students can access them whenever they are needed and can be repeated whenever they are necessary.

It does appear reasonable to conclude that efficacious IT managers will be supporting educators as they create more diverse and flexible learning environments than was necessary for previous generations of learners. The nature of the experiences central to the curriculum will determine the nature of the IT systems that are built and supported. A single approach to using technology in classrooms, or a single type of technology activity will not suffice for learners to participate in the emerging information landscape.

Pedagogical Technological Knowledge

The most efficacious development of pedagogical technological knowledge arises from those situations in which technologists (who obtain and configure test systems) scale up and deploy into production those systems that have been examined by and tested by teachers who identified pedagogical uses. Many of the information technology tools available in schools were developed for audiences and purposes other than education. It is only by investigating emerging technologies and adapting them for teaching that educators gain pedagogical technological knowledge. Those systems that appear to have the greatest pedagogical application with the least consumption of technical resources and the least extraneous cognitive load are those that deserve greatest attention and priority.

Consider social media as an example. Originally developed so that individuals could publish on the Internet (and still widely used for that purpose), many educators have found educationally relevant tasks that can be accomplished through social media, and these can be applied to pedagogical problems in many classrooms. The teacher who finds an excellent solution to a problem in her classroom (perhaps the biology teacher whose students have built an excellent model of a cell) can take a picture of the solution, and post it to a Twitter account. By embedding the feed in her online classroom, the solutions can become part of the resources for all students to use. This exemplifies the adoption of easy-to-use and effective technologies predicted by technology acceptance (Venkatesh et al., 2003).

Other examples of technologies with unexplored pedagogical applications include haptic and full-body motion interfaces (Malinverni & Pares, 2014) which allow for alternatives to keyboard and mouse inputs and for outputs other than printed documents or screen displays. Video games that track motions of bodies have been incorporated into some physical education courses and this is an example pedagogical technological knowledge affecting students' experiences. Virtual reality, in which technology provides three-dimensional content is another field of developing pedagogical technological knowledge (Ricordel, Wang, Da Silva, & Le Callet, 2017). As these technologies become more fully developed and less expensive, it is anticipated they will become more widely adopted for educational purposes.

Pedagogical Content Knowledge

Just as each content area has its own combination of concepts, ideas, and procedures, each has its own collection of activities that are well-suited to helping students learn that content. In many content areas, the methods used to teach are the lessons the teachers intend to teach. In science classes, for example, laboratory activities in which students plan and set up an apparatus so they can collect data, which they analyze are engaged in methods that teach both the content (the activities are designed to demonstrate important phenomena) and the methods (the activities give experience setting up experiments and analyzing data). Writing courses, also, find the boundaries between pedagogy and content blurred, as the coaching and advice students receive (and give) are intended to improve their writing as they gain experience writing.

Pedagogical content knowledge is an important aspect of on-going teacher education. It has been established that the cognitive and learning sciences are continuing to discover important aspects of pedagogy that were previously unknown and these lead teachers to adopt new methods or adapt their existing practices, so pedagogical knowledge is changing. It has also been established that content is rapidly advancing, so content knowledge is changing rapidly. As a result, the pedagogy used to teach content during a teachers' preparation is likely to be challenged by new discoveries in the learning and cognitive sciences. The responsibility of supporting teachers' pedagogical content knowledge falls largely to education professionals and leaders such as department leaders and curriculum leaders, efficacious IT managers will accommodate new demands and needs that are produced as educators continuously redesign and recreate their methods to reflect new discoveries.

Technological Content Knowledge

Technology is affecting how discoveries are made, and even what discoveries can be made, as well as how new knowledge is constructed in many fields. Consider mathematics-rich fields; spreadsheets, statistical software, and graphing calculators have reduced the cognitive demands of manipulating data for recent generations of workers (and students) in those fields. Further, citation management tools and online databases containing the full-text of periodicals has redefined the work of researching in many fields. During a teachers' professional preparation, he or she will gain experience using the tools employed practitioners in his or her field. In a classroom, many of the same tools will be available and many familiar tools will be replaced by new ones, so teachers must continue to develop and refine their technological content knowledge as it emerges over their careers.

Much technological content knowledge is developed in small and specialized groups, and it is developed to meet very specific goals. A group of math teachers, for example, may develop technological content knowledge around options for graphing functions on mobile devices. As handheld computers have become ubiquitous, students are likely to use many different graphing apps to solve problems. A group of math teachers may plan professional development time to sit with a collection of the problems they typically give to their students, and solve them using the many different devices and applications so they become familiar with the steps for graphing with different software and hardware options. After developing this technological content knowledge, they will be better prepared to both assess and evaluate the choices and support students who may be using different devices. As a result of improved technological content knowledge, tools that are easier to use and more effective are likely to be installed by IT managers and teachers are likely to be more efficacious in helping students use all tools to learn they content they teach.

Technological Pedagogical Content Knowledge

Mishara and Kohler's (2006) TPCK model differentiates seven different types of knowledge that are relevant to technology-rich teaching and learning. These are useful in deconstructing classrooms into aspects that can be developed and improved in isolation, but efficacious IT managers are cognizant of the fact that these types of knowledge influence each other. A complete framework for understanding teaching requires consideration of and reflection upon all aspects of TPCK; the tools we use (technology), how we use it (pedagogy), and what we teach with it (content) combine to create new and opportunities and challenges in the classrooms.

Efficacious IT managers also recognize that new understandings in one type of knowledge will create permanent and irreversible changes in the others, and that once changes in technology are made, the effects on the others will be permanent and irreversible. Consider IT managers who deploy a learning management system (LMS) so that high school teachers can take advantage of online testing features, resource sharing, and online discussion tools to support face-to-face instruction. Teachers who use that LMS are likely to adopt new approaches to teaching and assessment that are specific for the LMS, but they may find those expand their effectiveness or improve their efficiency so they become a permanent part of his or her practice.

Mathematics teachers can point students to web sites where students can vary the coefficients, exponents, and other constants of functions and the changes are immediately graphed. When I share such sites with students, it is common for one or more to observe, "It is like we were playing with the graphs." Such a site would affect the content knowledge introduced in the course, as it allows more sophisticated functions to be introduced more rapidly than they are without the technology. These sites also affect pedagogical knowledge of teachers as it introduces play into a topic that is not typically amenable to play and exploration.

It is also likely that those changes which teachers determine to be effective will be immediately adopted, they will exert peer-based social pressure on others to adopt it, and school leaders will exert leader-based pressure all teachers to adopt it. TPCK also provides a framework for ensuring a technological solution is extended and expanded only in those setting where they are appropriate, and inappropriate technology solutions are avoided. While the playful nature of interactive graphing sites can be useful for students who are developing a sense of the nature of graphs and the different effects of each term on the appearance of the graph, but play is unlikely for be effective when teaching students how to interpret graphs.

Efficacious IT managers will recognize the different pedagogical purposes of different technologies. Those who recommend a single tool for every pedagogical problem (or who interpret every pedagogical problem as solvable with a particular technology) are likely to be making decisions and recommendations for purposes other than teaching and learning. Deploying a single technology in every setting is an approach to technology planning that is not supported by leaders who understand TPACK.

Supporting Educators

We know that previous learning is an important factor in determining how new knowledge is perceived and what actions are taken in response to new knowledge, so it is reasonable to conclude that educators' TPCK begins developing long before they even begin their professional preparation and it extends throughout their careers. Efficacious IT managers have a role in ensuring all educators have opportunities to continue to learn about all types of knowledge that affect their decisions and actions related to technology and teaching. This on-going professional learning is necessary for educators to reconcile their existing practice and beliefs about teaching and learning and technology with new tools and discoveries.

While these learning activities sometimes fall within a single type of knowledge, the goal of all professional learning for educators should ultimately be undertaken to improve all aspects of educators' TPCK. Because TPCK comprises very different types of knowledge and skill, developing each necessitates different approaches to professional learning. Efficacious IT managers understand the differences between and support educators through training, learning, and design activities when each is appropriate. Further, they provide teachers with autonomy in making decisions regarding their professional learning when it is appropriate.

Training, Learning, and Design

Three types of learning experiences (training, learning, and design) are necessary to provide complete support of teachers' development of TPCK. Training, learning, and design are all professional development activities, but each is designed for different purposes and the type of activity depends of the nature of the desired outcomes.

Training is typically applied to those situations in which learners (trainees) must be able to perform procedures or actions after the activity is complete. When new hardware and software is introduced to classrooms, it is appropriate to train educators in how to use it. It is designed to overcome extraneous cognitive load and increase perceived ease of use. Training is typically organized using instructionist models. In face-to-face training, an expert will lead participants though procedures from the very basic steps through increasingly complex uses of the technology. Trainees follow directions and cues given by the expert, who assumes trainees have no experience in the tools he or she is to demonstrate (see figure 2.2). In training situations, teachers interact with technology, and the interaction is mediated through an expert

There are three outcomes of training in professional development settings for teachers. First, experts seek to make teachers aware of the capacity of the new system. For example, when deploying a new learning management system, training will focus on new or changed functions in the LMS. This is particularly important when new capacity is similar to existing capacity, such as differentiating threaded discussions boards from blogs and journals as tools for interaction in an LMS.

Second, training supports teachers' understanding of how to configure different tools. Although the details of how to set each option in not reasonable in training, it does focus on opening the configuration tools and being aware of where different options are found.

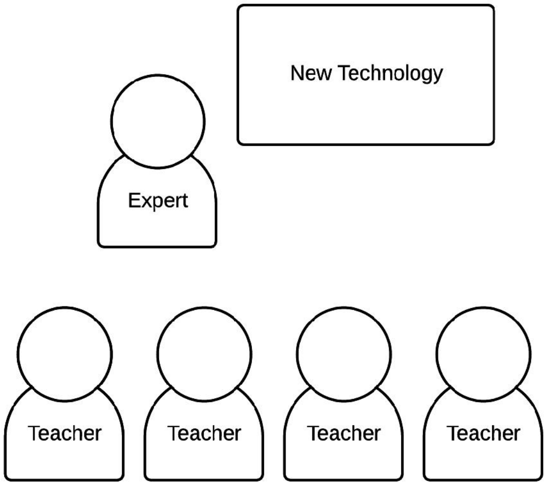

Figure 2.2. Training: teachers interact with technology, mediated through an expert

Third, training incorporates strategies for ensuring teachers can use the systems with independence after the training ends and this includes resources for further training. Most experienced trainers understand teachers are a diverse group, so multiple methods of developing independence are appropriate for training. It is not unusual for teachers who ask for step-by-step instructions to spend excessive time in training taking their own notes, so many trainers prepare only general procedures and encourage teachers to record the specific steps in language they understand. The opportunity for independent practice while experts are available for guidance and advice is another strategy. Yet another is providing tutorials, annotated screen shots, and video recordings.

Training is often focused on answering questions that begin with "How do I…?" and these are answered with specific steps or procedures. Because training is used to support teachers' knowledge of steps or procedures, IT managers can define the outcomes that will determine the success of the training. When participants have demonstrated a predefined level of capacity to use the technology, then the training can be deemed complete and successful.

Professional development focused on learning provides teachers with support as they understand the role of a particular technology in their teaching and instruction. As teachers learn about technology, they identify curriculum goals that are important and explore how technology tools can increase the efficiency of learning, how technology can provide more effective learning experiences, or how the technology can support a new curriculum goal (these often arise from new technological content knowledge). While students are rarely considered when planning and delivering training, teachers do consider how the technology will affect students' experiences when they are learning about technology (see figure 2.3).

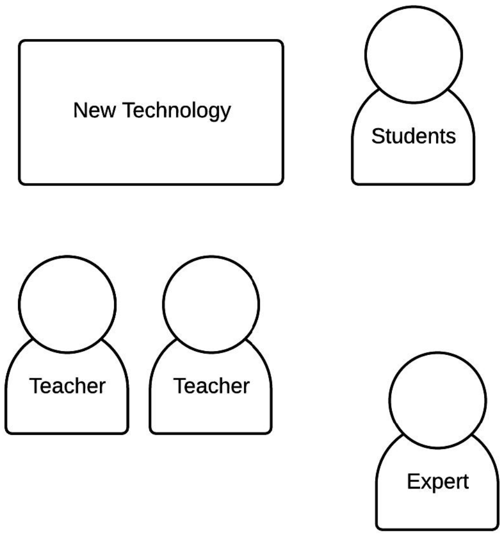

Figure 2.3. Learning; teachers considering technology in light of students with the expert playing a support role.

When learning, teachers tend to ask the question "Can I…?" and it is answered with an idea about how technology can be adopted and adapted to accomplish a curricular goal. Compared to training, learning about technology is unpredictable; experts can accurately predict the end products of training, but they cannot accurately predict what teachers will learn about technology. Compared to training, the changes in learners are much more dependent on the context in which the new knowledge will be used, the beliefs and values of the learners, and the purposes of the learning. Once educators become comfortable they can use a particular technology, they have proven the system can be operated and that it can serve a useful or expected function with reasonable effort, they begin to brainstorm the potential uses of the technology in the classroom, which is an important process in learning.

Learning is also an activity that can continue with no end. This is especially true when the purpose of the learning is to improve performance. Learners may end the process according to a predefined rule or through the decision to stop, but the rule is artificially set and does not represent an objective end point. In IT management, the artificial end of learning happens when the decision is made that "We understand what we want to do, now it is time to take action."

Once teachers are sufficiently familiar with a piece of technology, learning becomes a design process in which their work becomes more relevant and focused on refining materials and plans. In design work, teachers build solutions for the problems and they produce innovations as new methods for teaching and learning are created and integrated into classrooms. Design typically becomes an iterative process as teachers create a solution, then refine it as they observe how it works in the classroom (see figure 2.4).

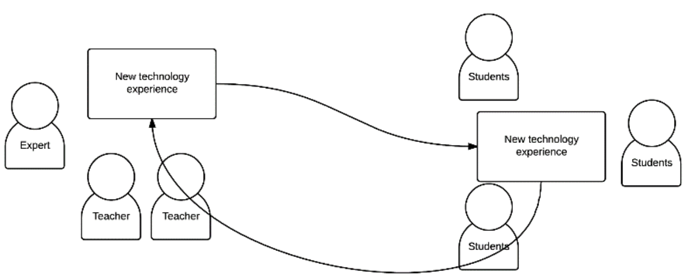

Figure 2.4. Design: teachers create IT experiences for students

Eric von Hippel (2005), a scholar who studies technological innovations, suggested lead users, those individuals who tend to develop new applications of technology are most productive and contribute the greatest innovation when they are provided with a toolkit that affords:

- *The ability to complete the entire trial and error process-* This is particularly important for innovations in education as designs cannot be tested unless they are used with learners in the intended situation. While pilot studies can help refine educational designs, redesigns must be informed by feedback from classrooms. Frequently, new educational technology designs are tested with other teachers before being deployed with students.

- *Design within the available solutions space-* Solution spaces are bounded by the controllable aspects of the local IT systems and budgets. Designs, for example, that require teachers to use expensive extensions to be added to the LMS will fall outside the solution space.

- *User-friendly tools-* When elucidating the technology acceptance model, Davis (1989) established the role of ease of use in the intention to use technology. This extends to toolkits for designing innovations; teachers are more likely to use tools they find easy-to-use as it is associated with more efficient work.

- *Modular libraries-* Modules are components that can be designed once and then reused for similar projects. A toolkit that provides this capacity will also lead to greater innovations in technology-rich teaching and learning. Mathematics teachers who use a toolkit with a graphing module can focus their efforts on using the module rather than recreating it for each course.

Whereas training is led by individuals with expertise and familiarity with the technology, learning and design tends to be led by experts in teaching. Etienne Wenger, Nancy White, and John D. Smith (2009), three scholars well-known for their work to understand communities of practice, have described a particular type of technology leader that emerges in many organizations; they call these individuals technology stewards. According to Wenger, White, and Smith; technology stewards are individuals who develop expertise adapting technology to achieve the strategic goals of the organization. In education, we expect technology stewards to be educators who develop greater than usual expertise using technology and the ability to share their expertise with others.

Because they understand the needs and the expectations of the members of the organization, technology stewards are given greater authority in technology decisions, and play an active role in evaluating tools and changes that are under consideration. In the often-used progression of technology projects, technology stewards are involved in determining the proof-of-concept which establishes a technology solution is possible; their advice usually determines which technology projects enter the proof-of-concept stage of planning. They are also involved in alpha testing (which finds a small group of experts determining if the systems provide necessary functionality) and supporting beta testing (which finds the first end users trying the system and providing feedback), and they serve as a liaison between educators who test systems and the technology professionals who will redesign systems to reflect what is learned during tests. When a system moves into production, technology stewards are active in training users, and helping them learn to use the systems, and design activities using technology. In many cases technology integration specialists will fill this role, but the focus of technology stewards' efforts is as much towards technologist and the decision they make and systems they build as it is on the decision teachers make.

Autonomy and its Limits in Professional Learning

Educators appear to have an incomplete and inconsistence awareness of autonomy as a factor that affects learning. Blumenfeld, Kempler, and Krajik (2006) define autonomy to include the "perception of a sense of agency, which occurs when students have the opportunity for choices and for playing a significant role in directing their own activity" (p. 477). Autonomy is implicit in many of the pedagogical strategies that are replacing the Standard Model and that are associated with 21st century skills. It is reasoned that learners who have autonomy are more motivated to study and more engaged with the curriculum than those who have little autonomy. Autonomous individuals approach situations with:

- The ability to recognize a problem, which is typically a gap between the current state and the desired state;
- Knowledge of how to resolve the problem or close that gap;
- The capacity to solve the problem or close the gap;

• The authority to implement their solution.

Despite the value of autonomy in creating classroom that promote deeper learning, there is evidence teachers are allowed to exert little autonomy over instructional practices (Range, Pijanowski, Duncan, Scherz, & Hvidston, 2014).

A limit to autonomy in IT management in schools is that the four aspects of autonomy are controlled by different individuals. Problems or gaps related to teaching and learning must be identified by teachers; knowledge of how to resolve problems must emerge from teachers and technology experts as they design and test IT systems. The capacity to scale test systems into production systems that can be managed with the available resources must be done by IT professionals, and authority to decided which solutions to implement is assigned to school leaders. Efficacious IT management has been constructed as a collaborative endeavor, thus it will lead to greater autonomy, even if it is filtered through others involved with ensures actions are appropriate, proper, and reasonable.

Compared to users of IT in other organizations, teachers do appear to require greater autonomy in technology decisions (Hu, Clark, & Ma, 2003; Teo, 2011), as educators generally are more independent users of IT and use a greater variety of applications and data sources than information workers in other fields, and they are more likely than users in other organizations to test new applications and data sources for usefulness. Autonomous educators who explore and discover effective uses of IT in their classrooms, must have procedures through which their new learning can be translated into IT systems that are available and supported by the IT management team.

Autonomy is a complex variable that affects decision-making and professional activity in a variety of ways. As will be explained in Chapter 8: Understanding Change, autonomy is necessary for change to occur, but individuals who exert autonomy may also reject the vision, direction, or structure of leaders who seek to affect change.

Chapter 3: Access to Sufficient Computing Devices

Technology-rich teaching and learning occurs only in those schools in which IT that has the capacity to perform the task is available and functioning. In recent years, the nature of devices available to the education market has changed, so IT managers deciding what to purchase and how to disperse it in the school. face more and more complicated options than they did previously. The factors that affect these decisions are explored in this chapter.

Computers are systems in the true sense of the word. For several decades, "computer" meant a box that rested on a desk; users controlled software that was installed on a disk inside that box and they created information by means of a keyboard and a mouse that were plugged into the box. The user saw output on a video monitor and sent output to a printer; those peripherals were also attached to the box. A surprisingly small computer chip was inside the box and microscopic circuits on that chips is where information was processed. That processor, along with random access memory (RAM), disk drives that stored information, and all of the input and output peripherals were all attached to a circuit board (called the motherboard). The peripherals are largely what give computer systems their capacity to facilitate teaching and learning. They have expanded in recent years and now include printers, 3D printers, network cards, video cards, sound cards, and all other input and output devices (of course with the increasing use of networks many input and output devices have been replaced with files transferred to and from other computers via networks). The various hardware and software components installed on a computer affect what can be done with the system and each component affects the operation of the others. Together they create a system; the whole is greater than the sum of the parts.

Logistic Goal

Technology-rich teaching and learning requires students use computing devices, so school IT managers will define a logistic goal such as "Students and teachers will have sufficient access to computing devices that are sufficient for the curriculum and learning activities." (The redundancy of the word "sufficient" in this logistic goal is recognized. It will be demonstrated that sufficiency can take many meanings and many factors affect what constitutes sufficient IT.)

Content of the Logistic Goal

In schools, sufficiency depends on the capacity of the systems to manage and process the information necessary to complete the task assigned to the learner, the number of devices available, and the capacity of the teacher to implement the plans they have designed. Improving any one of those factors can increase sufficiency; because schools rarely have inexhaustible resources, IT managers often find they must negotiate sufficiency.

Capacity of Devices

Teaching and learning requires students access and consume information, analyze and manipulate it, and create and disseminate it. Some educationally relevant information tasks, such as consuming text-based web sites (e.g. Wikipedia) and composing text (e.g. writing research papers) require little computing capacity. The rate of data creation is a small, so the necessary processing power is minimal, and the output is simple enough that a low-resolution display, and minimal network connection allows the work to be completed with no impediments caused by the technology. Other information tasks central to the curriculum, such as consuming or creating video require much greater computing capacity as the amount of data necessary to encode video is far greater than transferred for text. A device that is sufficient for a text-based activity may be insufficient for a video-based activity.

The capacity of a computer determines the nature of the information tasks that can be accomplished with it. Systems with greater capacity can process more data in a shorter time so users can use more sophisticated data sources and create more sophisticated data products using systems. When one attempts to use a computer with insufficient capacity, the computer is likely to "freeze" as it becomes unresponsive and many software features stop working. When a computer freezes repeatedly during a task, it lacks the capacity to perform the task.

Capacity is determined by several factors. In general, these factors determine the rate at which a system can access, process, and display information. Devices must be evaluated relative to a particular need, and IT managers will determine the capacity of the systems by evaluating:

- *The speed at which the computer can process information-* Processing speed is measured in giga-hertz (GHz); a processor operating at a speed of 3 GHz can perform 3,000,000,000 operations in one second. For the first generation of IT managers in schools, the processing speed of the computers was important as it determined the performance of the machines. For most of the 21st century, IT managers have been more concerned with the number of processors installed in parallel on the systems they purchase. The increasing processing capacity of computers has been referred to as Moore's Law, and it has continued unabated for more than 50 years.

- *The amount of random access memory (RAM) available to the processor-* RAM has always been important in determining the capacity of a computer. It is relatively cheap and easy to increase, so RAM upgrades are a common method of increasing the capacity of computers. For some devices and for some purposes, however, increasing the RAM will have little effect on the perceived performance of the system. For example, if a student is using a computer that has 4 GB RAM installed to access G Suite and its performance is adequate, then doubling the RAM to 8 GB is unlikely to provide any better performance.

- *The efficiency of the operating system-* The OS manages memory and other system resources, and the rate at which it performs these tasks affects users' perception of the computer's performance. Over time, updates and changes to the operating system can decrease its efficiency and computer systems on which excessive applications or extensions to the operating system or web browsers can also interfere with operating system efficiency.

- *The sophistication of the applications*- Applications are the software used to manage and create information; many appicatons are sold in different versions. For example, schools can install and support various levels of video editing software. IT users can select from simple video editing software (sometimes packaged with the operating system) up to the same software used by professional video editors. Professional level software provides very sophisticated functions, but it requires hardware be upgraded frequently and it requires time and effort to use at its fullest capacity.

- *The data rate at which the system can send and receive information on networks*- This factor is increasingly a determinate of sufficiency. For many users, the capacity of computing devices is less about information processing and more about interaction enabling. Access to networks also expands the information capacity of our devices.; we update our software through the network and we move photographs from our devices onto network storage systems to free memory for more images (for example).

These variable aspects of computing systems that determine its capacity cannot be considered in isolation, as each contributes to the others. Consider the smartphones that many of teachers and students carry into school in their pockets. These are the latest in a series of "pocket-sized" technologies that have been evolving for decades and these have evolved together with networks. The processing speed and memory in pocket-sized devices exceeds that available in desktop computers manufactured only a few years ago, they connect to networks that make multimedia content available, and they allow users to create and share multimedia content with little effort. These devices have evolved through a combination of manufacturer push and consumer pull; as devices made more tasks possible, the demand for the products increased and motivated manufacturers to further improve and expand the devices they sold. Perhaps the best example of this effect is the co-evolution of the displays and the network capacity to access video. Better networks afforded users capacity to receives video and improved displays make the viewing experience acceptable which increased the demand for networks capable of delivering video to users of mobile devices.

The reality of evaluating device capacity is even more complex than presented, as even more factors affect the capacity of some devices and the all of these factors continue to evolve. The battery technology necessary to power the devices in our pockets is one example. Improvements in batteries means they can to power devices longer than previous generations of batteries and they recharge more quickly. Network security is another. Engineers are developing more sophisticated methods of securing the networks we use and the data we store on them. Like other technologies, these methods are being refined through market pull and industry push but also through reaction to threats posed by the devices themselves and by misuse of the devices. The Internet of things (IoT) is the label given to the growing range of consumer devices that are connected to the Internet, and the IoT represents a vastly extended collection of source of input for computing systems, and it is possible because of increasing capacity of processors, expanding wireless networks, and decreasing size of circuits that has contributed to the mobility of technology.

Despite the evolution of a greater diversity of computing devices, which is likely to continue into the foreseeable future, schools are likely to be places where the original model of computing will continue to dominate technology-rich activity. Learning will find students accessing information, composing text, and creating media using general computing devices managed by the school and running software supported by the school. The fleets of devices managed by school IT professionals will be more diverse than the fleets managed by previous generations of IT managers. They will obtain, configure and install, manage and support computers with full operating systems, devices with mobile operating systems, and Internet-only notebooks.

Systems with Full Operating Systems.

Of the devices marketed to schools, those with the greatest computing capacity will arrive with full operating system installed on the hard drive. Full operating systems include Windows, the Macintosh OS, and Linux (and open source operating system that can be used for free) which are installed on desktop and laptop computers. Of the devices on the market at any moment, these will have the most processing power (with both the fastest and the most parallel processors), the greatest RAM, and support the most sophisticated applications.

Full operating systems are available in multiple versions, and publishers will maintain the versions for several years; eventually operating systems reach the end of life when the publisher no longer releases security updates. In addition to the versions of the operating systems installed on user devices, there are versions of these operating systems available for servers as well as for mobile devices. Full operating systems are designed to connect to servers and, together, the OS on the users' device and the network OS provide the most flexibility and most control of the software environment for IT professionals. They can be configured to use network resources, allow for multiple user profiles, and support network-based management. Obviously, the price of a unit will vary depending on the specifications, but IT managers who are asked about the cost of obtaining new machines that arrive with a full operating system are likely to estimate $1000 per unit.

These devices tend to have the greatest longevity of all of the computing devices available in schools. It is not unusual to find desktop computers still operating and providing educationally relevant functionality more than five years after they were first purchased and installed. Laptop models tend to last less than five years, as they get damaged through rough use compared to desktop models. Decreasing performance of batteries and other components also limit the functional lifespan of laptop computers as well. Over the life of a computer with a full operating system, users will find it is characterized by decreasing performance as operating system and application updates require more system resources. IT managers accommodate for this by decreasing the number of applications installed, so it can continue to be used for tasks requiring the least capacity.

The rationale for purchasing systems with full operating systems is typically grounded in the sophistication of the software that can be used on these devices. Students using a computer with a full operating system can use the same software that is used by professionals, so they can create sophisticated products. Further, they can use sophisticated output devices and peripherals. That software and those peripherals both add to the cost of the systems, but in many cases, that cost is necessary to provide the computing capacity necessary to meet the goals of the courses in which students are enrolled.

Consider, for example, a high school in which theatre students write and produce one-act plays. Teachers may be interested in having students record the performance on multiple cameras, then use those recordings to create a single video version of the performance that incorporates different views. Editing and rendering such a video requires sophisticated video editing software that can be used only on a computer with a full operating system. In addition, the size of the files that must be managed to produce and render such a project require the processing power and the amounts of memory that are available only on a relatively expensive computer system with a full operating system installed.

Mobile Operating System.

The two mobile operating systems that dominate the consumer and education markets are Apple's iOS (which is installed on iPads and iPhones) and Google's Android (which is installed on a range of tablets and phones). Microsoft makes a version of Windows available for mobile devices and the open source community also makes version of Linux available, but these are much as less-widely used than iOS and Android. Mobile operating systems do allow users to adjust the settings and configurations, but these devices feature a single user profile on the device, so the changes that are made affect everyone who uses the device; this fact limits the usefulness of mobile devices in some schools. It is not unusual or IT professionals to find school leaders become strong advocates for purchasing mobile devices once they realize the ease of use that characterizes mobile devices. Those school leaders are not always fully aware of the difficulty of managing devices intended for single users in a school where devices are used by many different users for many different purposes.

Among the populations that have found the greatest success using tablet computers that use mobile operating systems are those educators who work with special education students. A number of factors, including the mobility of the devices, the individualization that is possible with the apps installed on the devices, the multimedia nature of the devices, and the haptic control are all features that have been identified as useful for this particular population of students.

Devices with mobile operating systems tend to be more affordable than those with full operating systems. Depending on the size of the screen and the quality of display and size of the memory, the same IT manager who estimated $1000 per unit for desktops or laptops would probably estimate $400 per unit that uses a mobile operating system, but he or she would be hesitant to make a final estimate before the option for managing the devices was specified. For example, some IT managers who purchase iPads decide to purchase a desktop computer and reserve it for the purpose of managing the devices through a third-party system.

A further concern for deploying devices with mobile operating systems is the capacity of the wireless network. Mobile devices are designed to function the best when they are connected to the Internet. While users can take pictures, record video, create documents, and otherwise be productive on a mobile device with no network connection, there are limited options for adding software, sharing files, and otherwise using the devices when they are not connected to the Internet.

Internet-only Operating Systems

The newest type of device to enter the educational market is the Internet-only notebook. When these devices were first marketed, they had no functionality without the Internet, but later generations have added some offline functionality. Still, however, these devices are most useful in schools when they are connected to the Internet.

The dominant device used in school that uses an Internet-only operating system is the Chromebook which is available from many manufacturers and in several configurations, but that all use the Google Chrome OS. With this device, one logs on to the device and the Internet simultaneously using a Google account. The only applications installed on the notebook is Google Chrome, which is the popular web browser. Productivity software (such as the word processor, spreadsheet, and presentation software) is provided through the user's G Suite account; all other productivity tools that are used on the Chromebook must be available via a web service.

There are limited options for using peripherals on a Chromebook, and printing is managed through Google's Cloud Printing service. This service requires an administrator of the school's Google Domain to configure a computer to be the print server, and it accepts and processes print jobs from any user assigned to the cloud printer.

Managing a fleet of Chromebooks in a school finds an IT professional logging on to the online administrative dashboard provided by Google and selecting for the options available from Google or from third-party publishers; Google has a history of providing both G Suite and Chromebook management tools at no cost to schools, but many third-party services require a paid subscription. In addition to being limited by the options provided by Google and its partners, the decision to purchase Internet-only devices for students and teachers makes a functioning wireless network absolutely necessary in a school.

Of the three types of devices marketed to school IT managers, Internet-only notebooks are the most affordable. The IT manager making a rough estimate of the cost would likely give $300 as a price per unit. That estimate would depend, of course, on the capacity of the wireless network in the school where to devices were to be deployed. The actually cost of deployed functional Internet-only devices may depend on upgrading network capacity.

Availability of Devices

While an undergraduate student studying science education, I judged a science fair at a middle school located near the university where I studied. In my journal, I noted, "Students had printed graphs of their results and taped them on their displays." I also recorded my conversation with the teacher, "she said they drew their graphs on paper, and then when she had approved them, they went to make them on the computer and printed them out." I also had a sketch of one of the science classrooms which showed the location of the two desktop computers on the counter in the back of the room. In the same journal, I recorded a visit to another school a year later; during that trip, I joined a teacher with her students in the computer room. I observed, "students work in pairs on their Oregon Trail trip, taking notes on their trip;" the students then used those notes to compose a narrative of their voyage. My record of the conversation with the teacher detailed, "the Westward Expansion social studies unit is three weeks long and the students work on this during our time in the computer room."

In those two cases from the mid-1980's, we see computers being relatively marginalized and specialized part of the curriculum. In both cases, there was a very specific purpose of using computers, and the teachers played an active role in scheduling and controlling access to the machines. In the graphing example the teacher appears to have deliberately slowed the process of digitizing the graphs by insisting they be approved on a paper copy before the students accessed the computer. In the Oregon Trail example, the role of the computers in the curriculum was different as all students were using computers at the same time, and I noted in my journal, "the teacher encouraged students to work quickly as this was the last day in the lab."

Those cases also illustrate one of the first major transitions in how computers were made available to students in schools. When they first arrived, desktop computers were installed one or two at a time in the classrooms of teachers who wanted them. Once installed, they were used in ways the teachers directed, and students used the computers while classmates were engaged in non-computer activities. This model is illustrated in the graphing example. As computers arrived in larger numbers, and the demand for instruction about computers increased, large numbers of computers were installed in special classrooms (usually rooms that had been retrofit with additional electrical receptacles). Once computer rooms were installed, the model of technology-based teaching changed. Teachers would "take their classes to the computer room," and all students would use computers at the same time (usually for the same purpose), and no student used them until the class returned to the computer room during their next scheduled session.

Around the turn of the century, it was reasoned that students needed experience using computers in their classrooms where their other learning materials were located and to demonstrate the computers were useful for all learning not simply for specialized activities. "Technology integration" became the preferred model of technology-rich teaching. Technology integration was possible because of the coincident maturing of mobile computers and wireless Ethernet, so the computers that were moved into classrooms could be connected to the network. Of course, one cannot ascertain which of these was the motivating factor, but technology integration, mobile computers, and wireless Ethernet all arrived in schools at about the same time.

In the 21st century, it is common for IT managers to provide computers to teachers and students in three ways. Computer rooms, both (in-place and mobile), one-to-one initiatives, and bring your own device initiatives. Each has implications for IT management and for technology-rich teaching and learning.

Computer Rooms and Other Common Resources

While computer rooms have largely fallen out of favor, they continue to be maintained in many schools. As more diverse computing devices have entered the educational market and Internet-only notebooks became more popular, computer rooms have become more important for providing capacity for specialized purposes that require sophisticated software that must be installed on devices with full operating systems installed and that meet other hardware requirements.

For example, high school students working on the school newspaper may use their smartphones to capture images and draft stories using G Suite which is accessed via Chromebooks. When the students prepare the newspaper to print, however, they will use desktop publishing software that is installed on workstations in a computer room. That software allows for far greater control over the layout of the printed newspaper (and the production of electronic editions) than is possible to devices with less capacity that are used for early drafts of articles. Both are necessary for producing the final product.

While some computer rooms are filled with newer desktop computers with the greatest capacity of the various machines deployed in the school, other computer rooms are filled with the oldest machines. In schools, IT managers tend to extend the life of devices as long as possible to ensure long-term value from the purchase, so older computers are nursed along with little software installed and provide minimal, but still useful, functionality. Teachers whose students need to find information on the Internet or who need to create word processor documents, presentations, or spreadsheets may find a five-year-old desktop computer with only an office suite installed to be perfectly sufficient. Some faculty even prefer to use such systems with their students as they provide fewer distractions to students than systems with more tools installed.

One strategy that has become popular (among some IT professionals in schools) for leaving computers in service when the operating system is no longer supported is to install Linux on the computers. Linux is an open source operating system, so it can be installed without paying licensing fees, and it tends to be updated by the community indefinitely, and it (generally) requires less processing capacity than commercially available operating systems, so it can stay in service longer and on older machines. A teacher who creates a valuable lesson using a particular Linux application will find it continues to be available, in an unchanged form for as long as the computers are functional. A teacher who creates a similar lesson using a web-based application or a commercial operating system may find the site removed or the application becomes incompatible with the operating system before he finds a more suitable replacement.

Even in one-to-one environments, there are situations in which teacher must share computing resources. This can include computers with full operating systems, specialty printers, high resolution projectors and similar devices. Such devices that cannot be provided in indefinite numbers must be shared among teachers. The need to share and access to those resources and schedule time and activities so that everyone has similar access is a part of managing the technology-rich classroom. Sufficiency decisions must be made with the respect to the other demands of financial and support resources, and one support system that must be maintained by the IT professionals is a public system for viewing schedules and reserving time to use shared devices. It is reasonable to insist such schedules be available and that teachers use them.

One-to-one Initiatives

The state of Maine, in the northeastern United States, is widely recognized as the first large jurisdictions to implement a one-to-one initiative when the state purchased Macintosh laptops for each seventh-grade student starting in 2002. The rationale behind one-to-one initiatives is that it ensures all students will have access to a computer at all times and in all places in the school. One-to-one initiatives have become more widespread as Internet-only devices (which we have seen are a fraction of the cost of laptop computers) have become more popular. Beginning a one-to-one initiative does introduce several complications into IT management.

Some IT managers deploy on-site one-to-one initiatives, which means each student is assigned a device, but it stays at school. While this does minimize the risk to damage of devices while they are being transported and loss of devices (or power supplies) when they are off campus, it does restrict the technology-rich activities to the school building.

A reasonable case can be made that on-site one-to-one initiatives put disadvantaged populations at a further disadvantage. If the one-to-one device is the only computer to which the student has access, and if access to the device is needed for off-campus learning, then restricting a students' use can limit his or her opportunity for an education. One-to-one initiatives that deploy Internet-only devices can also be criticized because of the demand it puts on families to purchase Internet access and to install a wireless network at home, so the school's device can be used (to its full capacity) there. Further, if individual students do not have devices (because it is not charged, or it is broken, or has been taken away for violating the acceptable use policy), then the student's ability to engage with the curriculum may be diminished.

When deploying devices one-to-one, IT managers also take care in writing and communicating a clear acceptable use policy. This is especially important with devices that are taken home, and are going to be used on networks and in settings that are not protected and managed in the same way that a school network is.

IT managers also must plan steps to improve technology support so one-to-one devices are repaired quickly. These steps include seemingly simple, but often overlooked, steps such as providing power strips so laptops can be used even if they are not charged, and purchasing extra devices so spares can be deployed while malfunctioning devices are repaired. Many schools that deploy one-to-one initiatives will configure the devices so that files saved on the local disk drive are automatically synchronized with a cloud storage system (such as G Suite) which minimizes loss of data when computers fail. All of these support steps can increase the total cost of owning devices in ways that are not predicted when the initiative begins.

Bring Your Own Device

While a one-to-one initiative is designed to ensure that all students have consistent access to a computing device that is provided by the school, bring your own device (BYOD) initiatives are those designed to deploy a one-to-one initiative in which students and their families purchase and own the devices they bring to school and use to interact with the curriculum. These efforts are grounded in the observation that students arrive in school with smartphones and laptops, and there is even evidence suggesting parents are willing to provide devices for their children to use in school (Grunwald Associates LLC, 2013). Deploying a BYOD initiative does have important implications for both teachers and for IT managers.

First, because the device is not owned by the school, IT managers can exert minimal control over what software is installed. Consider the mathematics teacher teaching in a BYOD environment. She may encourage students to use their devices to graph functions. While she may have a preferred tool, students may arrive to class with a variety of graphing tools installed on their devices, so she may face the challenge of supporting students as they use many different tools. Further, students may be less able to help each other if they are using different tools. Of course, some perceive this to be an advantage of a BYOD initiative, as students are likely to be exposed to many different tools for (in this case) graphing functions, so they are becoming more adaptive users of technology than if they are taught on a single device. This situation can also motivate professional development such as that described in "Chapter 2: Technology-Rich Teaching and Learning."

Second is the problem of providing software. A teacher who has prepared a template for an assignment using Microsoft Word, for example, may find that students who do not have that program installed on their devices may be unable to work with the template. Either the teacher must make the resources available in a manner that can be opened by every device, or Word must be provided to every student and on every device. While the common use of cloud-based productivity suites (see "Chapter 5: Web Services") is minimizing the instances of the problem, it remains and can be problematic, especially if learning activities include tasks that require the advanced features of applications.

Third, the school has little control over how the device is configured, so BYOD can increase the need for malware protection and other steps to ensure the security of the network and the school's data. In many BYOD environments, procedures are in place for ensuring devices that connect to the school's network meet minimum security standards, and network administrators in these schools are prepared to prevent devices known to be malicious from connecting to the network.

Finally, the expectation of support can be problematic in BYOD situations. Technicians employed by the school cannot be expected to provide troubleshooting and repair services for the diverse collection of devices used in a BYOD school. Further the school must assume liability for damage done when their employees provide service. The result is that BYOD initiatives may find students without devices as they await repairs by other technicians, and they may find their devices quarantined from the school network if it is found to be the source of malware. These can all limit students' access to devices that may be necessary for their education.

The Reality

In the preceding sections, several models of dispersing computing devices in school have been presented. It is unusual to find schools in which a single method is used. Especially as Internet-only devices have been purchased, computer rooms are maintained for projects necessitating greater capacity, and many educators use mobile devices for professional purposes (and encourage their students to use mobile devices for educational purposes). Consider Riverside School, a hypothetical small rural school enrolling students in grades 7-12. Riverside has a one-to-one program for students in grades 9-12; each high school student is given a laptop with the Windows operating system installed and full productivity suites, along with a host of other tools that are used in specific content areas. About 15% of the students decide to provide their own device (usually a Macintosh laptop) rather than using the computer supplied by the school. The IT managers have purchased "take home rights" for some software titles, so students can install licenses purchased by the school on their own computers while they continue to be enrolled, and students are pointed to open source software to install for some classroom activities. In addition, there are carts with laptops shared amongst the classrooms in each wing of the school; those laptops are used primarily by students in the middle school grades who are not yet included in the one-to-one initiative.

Further, there are two computer rooms in the school. One is located in the library and it is filled with older machines nearing the end of their life. These desktop models are used for accessing

Internet, including G Suite, the school's cloud-based productivity tool. Some teachers prefer to use that space rather than laptops in their classrooms as the library affords more space. The other computer room is filled with 16 newer and more powerful desktop computers than those available in the library. That space is used primarily for desktop publishing, digital photography and video projects, and other specialized courses and projects. This leaves teachers with options. They can choose the system that meets their need, and the needs of all users can be met with minimal disruption.

Capacity of Teachers

To this point in the book, teachers' technological pedagogical content knowledge (TPCK) (Mishra & Kohler, 2006) been proposed as a theoretical framework that affects teachers' understanding of technology and its role in the classroom. It is reasoned that teachers who have access to sufficient devices and who have developed sufficient TPCK will use technology for teaching and learning. This is not always, the case, however. Baldwin and Ford (1988) suggested the transfer of lessons learned in training to action depends on a) the training design, b) characters of the individuals, c) and the work environment. Among the most important aspects of work environment that determine the degree to which training and new learning leads to changes in professional action is the availability of mentors and the availability of resources. Efficacious IT managers will employ professionals who serve as mentors to teachers and also support systems whereby curriculum and instruction resources can be stored and shared.

Technology Integration Specialists

For decades, those responsible for organizing and presenting in-service professional development for educators have used a variety of models for providing learning experiences for teachers, and these have been designed to support all aspects of TPCK and to accommodate the needs of individual learners. These activities tended to reflect training in other professional organizations (especially for technological knowledge) and graduate courses (especially for pedagogical and content knowledge), so the professional learning occurred largely outside of the classroom and in the absence of students. In recent decades, professionals who are given various titles but who function as technology integration specialists have emerged as a specialty within the teaching workforce. These individuals are typically licensed educators who have received additional training (often earning advanced degrees) in educational technology. These individuals play active roles in as technology stewards (Wenger, Smith, & White, 2009) who advocate for technology solutions aligned with teachers needs and they also fill the role of lead user (von Hippel, 2005) who create innovative uses of technology in the classroom and disperse those innovations.

Mentors with greater than usual expertise have been found to be a characteristic of communities and organizations in which innovations are accepted and diffused. Eric von Hippel (2005), a scholar who studies innovation in diverse organizations and fields, notes lead users "are ahead of the majority of users in their populations with respect to an important market trend, and they expect to gain relatively high benefits from a solution to the needs hey have encountered there" (p. 4).

Technology integration specialists who serve the role of mentor participate in planning and delivering training, promote learning about the role of technology in learning, and support design efforts. In addition, these professionals play an active role in modeling and coaching mentees. Technology integration specialists are often found in classrooms (or computer rooms) when teachers are using technology for teaching and learning. In this role, he or she supports both the teacher and students in their activities. In some instances, these specialists will even teach classes (or co-teach), so the teacher can find a comfortable entry point into using technology.

In idealized circumstances, technology integration specialists spend most of their time supporting colleagues as they become competent and confident so they develop as independent users of and teachers with technology. Three common obstacles do interfere with the work. First, especially in smaller schools, a technology integration specialist may have fill this role on a part-time basis and have other teaching responsibilities. This can introduce scheduling conflicts that can limit opportunities to work with some other teachers. Second, the personal characteristics of some teachers may lead him or her to become dependent on the support of the technology integration specialists. Self-efficacy has been widely studied and appears to affect the intention to use technology and the transfer of that into practice (Abbitt, 2011; Yerdelen-Damar, Boz, & Aydın-Günbatar, 2017), and there is tendency among those with low perceived self-efficacy to rely on support to meet minimal technology expectations for their classrooms.

Third, because technology integration specialists are among the most visible technology professionals in the school, they are often the first contact for initial troubleshooting help. While this often leads to quick repairs and can lead to opportunities for both students and teachers to receive lessons in troubleshooting, this work does direct technology integration specialists away from their primary responsibility of mentoring teachers.

A final mentoring role for technology integration specialists is to support IT professionals as they develop experience creating systems to meet the unfamiliar needs of educational populations. They advocate for teachers' and students' needs when IT professionals are designing and configuring IT systems, and they interpret educational users' experience so the IT professionals understand unmet needs and systems that are perceived to be too difficult to use or ineffective.

Curriculum Repositories

Teachers' capacity to use technology in classrooms is also improved by the easy availability of technology-based activities and lessons that are aligned with their curriculum needs. Dexter, Morgan, Jones, Meyer (2016) observed that accessible resources (those that could be incorporated into classrooms with minimal adaptation) were associated with greater use of technologies. This led those scholars to conclude, "leaders must provide unfettered access to technologies beyond personal computers… and provide learning experience in the pedagogical strategies that support integration those technologies into teachers' instruction" p. 1208). Curriculum repositories (Ackerman, 2017) are systems that facilitate sharing of resources and strategies among the professionals working a local community.

A curriculum repository is an online space, typically a course created in the learning management system provided by the school, where educators can engage with each other to find and create resources to support all types of TPCK. Training that is part of on-boarding new teachers is necessary so they are prepared to use those systems; by posting the materials used during those training sessions to the curriculum repository, IT managers can make the repository a valuable resource for educators when they first arrive.

Curriculum repositories are often modeled after existing open education resource (OER) communities. Several communities of OER developers have created web sites where visitors can search for and find documents, media, simulations, and other resources created by members. These sites are available to general users of the Internet, and membership is lightly restricted, so these tend to be vast and rich repositories that many users find them overwhelming. Curriculum repositories are modeled after OER sites as users can upload and curate and share resources, but the collections are more limited and participation is restricted to teachers (and others) in local communities, so the resources tend to me more closely aligned with specific curriculum expectations and the they tend to be created by individuals with similar technology available.

Negotiating Capacity

This chapter focuses on the need for efficacious IT managers to provide access to sufficient devices so that teaching and learning needs can be met. Sufficiency is a complex concept grounded in:

- The number of devices that are available (too few impedes sufficiency);
- The nature of the devices (to little capacity impedes sufficiency);
- The manner in which the devices as available (more inflexible options limits sufficiency);
- The preparation of teachers and the support they receive (teachers who lack the competence or confidence to use technology impede sufficiency).

Each of these factors can be limited (for example by budgets or other resources), so the sufficiency of devices is often negotiated, and IT managers seek to improve access to minimize the adverse effects of these negotiations on teaching and learning.

Price versus Capacity

When making purchase decisions, IT professionals must negotiate cost and capacity. In general, devices that have greater capacity are more expensive; this can be seen in comparing the cost and capacity of devices with full operating systems (most expensive and greatest capacity) with Internet-only devices (least expensive and least capacity). There is an inverse relationship between cost and capacity and the number of devices that can be obtained per unit of a budget. Using $1000 as the estimated price per unit of devices with full operating systems and $400 as the estimated process per unit of Internet-only notebooks, IT managers would budget $25,000 for a classroom full of computers, but only $10,000 for the same number of Internet-only devices.

While the lesser cost of the Internet-only devices may motivate IT managers to opt to purchase those devices, they are going to provide limited capacity on each device. The result is that IT manager must reconcile financial considerations with educational considerations. To avoid limiting educational options through their technology decisions while also minimizing the cost of purchasing devices with greater capacity than is necessary, IT managers can diversity the fleet of devices they manger. They can purchase a large number of inexpensive devices with minimal capacity, and small number of devices with greater capacity. This strategy makes the most devices available for the least demanding (but most frequent) information tasks (such as using word processors) while also making some devices available for the most demanding (but least frequent) information tasks.

Further, those devices will affect decisions about the network, and may result in changes to how technology personnel do their work. In all cases, it is the instructional users who must decide the sufficiency of access. School and technology leaders who reject decisions that emerge from instructional users must take responsibility and be transparent. If the devices are “too expensive,” then the school leaders must articulate that and defend the decision. If devices are “too complicated” to install and maintain with the current level of knowledge or staffing, then that rationale must be made clear, and school leaders must support IT professionals so they can manage the systems teachers need.

There are no heuristics that can be used to determine what is appropriate levels of and types of technology useful for students, and in many cases, a diverse fleet of devices affords the greatest pedagogical uses, but requires the greatest expertise for managing it. As a student proceeds through her day in a typical high school, she may encounter a variety of information tasks that each require a different type of device.

Capacity versus Information Task

Another common negotiation is between the available capacity and the nature of the information task in the curriculum. In situations in which the complexity of the information task is beyond the capacity of the devices, teachers may reconcile the complexity of the tasks with the capacity of the devices. Consider video editing, which is a task that can be completed on a range of levels. While Internet-only devices may be sufficient to access and a web-based video editing system, those systems provide far less video editing capacity than a full video editing application. (These limits include the length of the video that can be produced, the options for editing it, and the resolution of the final product.) Especially as students gain experience and seek to create longer and more complicated video products, the browser-based products will be insufficient.

Teachers must decide when their students and their goals have extended beyond the simple tools and full applications are necessary. This negotiation is informed by the nature of the students, the goals of the video project, and the availability of the full devices (which might be shared among many teachers).

IT managers must recognize that the information tasks teachers anticipate including in their lessons are likely to become increasingly complex over time. As teachers' and students' skill increases, they will expect to include greater capacity more frequently. A solution that provides low levels of complexity, but that can be accomplished with minimal capacity may prove insufficient as skill increases. Efficacious IT managers will respond to changing levels of expertise in teachers and they will also attempt to be proactive by anticipating need and encouraging teachers to participate in IT planning.

Educational Usefulness versus Device Management

In the previous sections, an oversimplified version of technology decision-making has been presented. Cost (a very important consideration for reasonable decisions) and computing capacity (also important in consideration for ensuring sufficient computing is available) have been identified as the factors relevant to purchase decisions. While cost and capacity may be the dominant factors when deciding how to provide sufficient access, other characteristics of the devices will have implications for which devices are purchased and how they are deployed.

Boot speed, which determines then length of time it takes for a user to power a device on and have it ready for use, is an important factor in many educational situations. A slow boot speed can lead to students being distracted from the learning task or frustrated that he or she is falling behind others. A device with a full operating system is likely to have the slowest boot speed; especially older models of desktops and laptop computers that store the operating system on a mechanical hard drive which is slower to start than one that stores the operating system on a solid state hard drive. In most schools, devices that run a full operating system also connect to a server to authenticate users and to load permissions and other services. All of these factors can extend boot time to the point where it impedes some educational uses of the devices.

Further delaying boot time in some configurations of full operating systems is the need to install updates. If computers have been unused for an extended time (for example during a school break), then the first users may find the devices will not function until updates are installed. In some cases, a computer can be unusable for tens of minutes while updates are installed. To minimize the disruptions due to slow boot time, IT managers can purchase devices with solid state hard drives or they can purchase devices with mobile or Internet-only operating systems.

For several decades, enterprise networking has provided centralized control of user accounts. In the typical enterprise network configuration, users authenticate against a single directory, and the user is assigned to groups depending on his or her role in the organization. Access to network resources (such as file storage, printers, and applications installed on servers are all controlled by rules managed by the network operating system that manages those permissions on the device with full operating systems. Many of those permissions were set to control access to devices and to prevent unauthorized access to network resources. The arrival of mobile devices and Internet-only devices challenges the methods of network management and security that are well-established; these new devices cause IT system administrators to change their practices.

As teachers develop greater technological pedagogical knowledge (TPK) of the devices they have available, it is reasonable to expect they will discover and refine more sophisticated uses of the devices they use and that they will seek capacity beyond that provided by existing technology. For these reasons, efficacious IT managers avoid single-device fleets. Although these can provide easier management and consistent capacity, they can result in schools maintaining unused capacity and can limit access to devices or to devices with sufficient capacity. The pedagogical implications of sections may be unpredictable to IT professionals and the management implications may be unpredictable to educators.

CHAPTER 4: IT NETWORKS

Especially as Internet-only devices have gained in popularity, a robust and reliable IT network has become essential infrastructure in schools. These networks connect students and teachers to data, information, and interaction within the local community and across the Internet. Whereas educators once deferred to IT professionals in the design and deployment of IT networks, they can no longer avoid knowledge of and input into how these systems, which are vital to teaching and learning, function.

Computers were originally designed to accept input (especially mathematical information), manipulate it according to rules programmed into the device, then create output (typically on paper, video monitors, or magnetic tapes). Once the capacity for computers to send output to other computers emerged, the first networks were created. As the number of computer systems increased (and the amount of digital data increased), there was increased value in connecting them so that information could be shared between them and users could operate the machines from remote locations.

Despite being used by academic researchers and the military for decades, networked computers did not become widely used in the consumer and education markets until the mid-1990's when hypertext transfer protocol (the origin of the http:// that begins web addresses) was added to the Internet protocols. The World

Wide Web (built using hypertext markup language or html) was developed which opened the Internet to vast numbers of users, and both the hardware and software for connecting desktop and laptop computers to the Internet became a standard part of almost every computer system.

Since the turn of the century, computing and networking have become almost synonymous. Many devices are of limited usefulness without a connection to a network, personal data and files are stored on web servers, and applications are increasingly accessed via web browsers. For the first generation of school IT managers, much attention was placed on obtaining computers for students to use, and only after they had large fleets of devices did they turn attention to developing robust local area networks for instructional purposes. Increasingly, local area network (LAN) resources are being replaced with services provided via web browsers (which are described in "Chapter 5: Web Services"), and access to those depends on reliable and robust networks. All of these changes, and the deep dependence on networks for teachers and students to access educational materials, make an information technology network an essential part of school infrastructure.

Logistic Goal

Efficacious IT managers will articulate a logistic goal such as "The school will create and maintain a robust and reliable network (including a wireless network) for students, faculty, and staff to access the LAN and Internet."

Context for the Logistic Goal

The adjectives "robust" and "reliable" are used to describe IT networks. Robust describes the capacity of the network to provide a connection that delivers the network information that each requested in a timely manner. A robust network will allow many users in a classroom to connect with little delay, and there will be little latency observed in the network traffic. (Latency is the term used by IT professionals to describe slow connections which cause performance of web services to suffer.) Reliability refers to the amount of time the network is available, accepting new connections, and sending and receiving authorized data packets. In general, a network that is not robust will fail when a large number of users connect, while one that is unreliable will fail intermittently regardless of how many users are connected.

For most computer users in schools, “the network is down” (because it is not reliable or not robust) is an unacceptable situation, so IT professionals seek to improve the capacity of the network to provide and maintain connections and manage network traffic. While IT professionals understand the work of building and managing reliable networks, collaborative IT management depends on educators who understand the nature of the network as well as school leaders who understand enterprise networks so they do not place unreasonable demands on the IT professionals. The intended audience of this chapter is the school leaders and teachers who are involved with efficacious IT management, but who are unfamiliar with the many aspects of enterprise networks. The purpose of this chapter is to provide an overview of the hardware, software, and practices of managing networks; all of these can be upgraded to improve the performance of school networks. For IT professionals, this chapter represents the information they should expect the educators who are involved in IT management to understand. It is upon this level understanding that educators can begin to grasp the nature and challenges of IT management.

Networking Starts Here

Opening the door and peering into the wiring closet where network devices are installed can be an intimidating experience. These rooms tend to be filled with white noise (generated by fans moving air which is cooled by air conditioners that operate day and night during all seasons) and racks of switches with large tangles of cables connected to ports with blinking green (or at least you hope green) lights indicating healthy connections. Other devices found in those rooms have far fewer ports and cables, but they are the most important devices as one (the unified threat management appliance) protects the network and its data from malware (viruses) and other threats (including hackers who attempt to hijack your data for ransom or use your network to their own purposes) and another (the gateway) connects all of the devices on your network to the Internet.

It is possible to “break” the network by disconnecting the wrong cable or turning off the wrong device in the wiring closet. To keep the network safe, the prudent IT professional will secure the closest and the devices it contains, but the prudent school administrator will understand how to gain access if necessary.

Who has access to the IT network can be a contentious topic in school IT management. IT professionals know how to configure it and they (very reasonably) want to minimize unskilled and unauthorized individuals from accessing it. School leaders can generally be considered unskilled in regard to IT network administration, so it is reasonable to limit their ability to access certain features of the network configuration. At the same time, school administrators are the individuals who are ultimately responsible for what happens in schools and who might need to take steps to prevent previously authorized individuals from accessing the network. In most situations, IT professionals and school administrators are professional and ethical (even when they disagree), but IT networks (and the data contained on them) are too valuable to be controlled by too few individuals.

As computers and networks have become vital for school management and teaching and learning, it is no longer appropriate for school leaders and teachers to avoid understanding the many services that keep the IT networks in their schools functioning for students and teachers. Everyone involved with IT management in schools must be able to differentiate local area networks from the Internet (to understand the total costs, management options and limitations, technology support); and also differentiate consumer, business, and enterprise networks (and the complexities of the management tasks that arise from large scale networks).

Local Area Networks

Local area networks (LAN) entered most educators' experience in the mid-1990's when the first servers to be regularly accessed by teachers and students arrived in schools. Early uses of LAN's in schools included connecting multiple computers to a shared a printer and sharing files using a folder (or directory) on a server which multiple users could access. As educators began to understand the advantages of networks, the LAN's in buildings became connected in more sophisticated ways. In many school districts, different campuses were connected to a single LAN so teaching resources developed in one school could be used in another, computers in different buildings could be accessed from a single location, and business operations could be consistently and efficiently managed from all sites.

In textbooks that introduce computer networks, readers often find descriptions of metropolitan area networks which are networks that extend across cities. Few network administrators use that term, and school IT managers are likely to hear IT professionals refer to the LAN which connects users access across many campuses. In rural areas, LAN's can connect schools separated by many miles.

As Internet technologies matured and became more sophisticated, they have been used for many purposes that were once fulfilled with servers located on local area, but LAN's continue to be an essential aspect of school infrastructure. The easiest way to differentiate the LAN from the Internet is to answer the question "Who has physical access to and control over the devices?" Those that an individual can physically touch in a school building are part of its LAN, otherwise it is likely an Internet resources. Of course, actually touching a server requires access to the locked wiring closet where they are secured; select IT professionals and school leaders should be the few who have keys to those doors. Network users also access many LAN and Internet services via web browsers another application, so the experience of using network resources often is the same for LAN and internet resources for the user.

As the boundaries between the Internet and LAN services have blurred, it has become more difficult to predict which services are provided by LAN resources and which are provided by Internet resources. Consider the example of library card catalogs. The long drawers filled with index cards documenting a library's collection were replaced with databases decades ago. (I used the drawers until I earned my undergraduate degree in 1988. When I returned to the same library two years later when enrolled in a graduate course at the university, the cabinets had all been replaced with computer terminals.) Because the databases containing library catalogs are large and they are accessed frequently, the first digital card catalogs tended to be installed on LAN servers. Requests to view records were sent through circuits to a server located quite close to the client computer from which a library patron requested the record. Technicians and LAN administrators configured and managed the hardware and software that made the card catalog available to library patrons by going to the library and unlocking the closet where the computers were running.

As we will see in the next chapter, card catalogs are now web-based services and schools pay a fee to store their card catalogs on the Internet. Librarians continue to maintain the database storing their collection, but the computers on which the information is stored are maintained by technicians at other sites (sometimes sites far removed from the school). This change has been possible, in-part, because the network connections between the library and Internet are sufficiently robust and reliable that patrons get library information as quickly over the Internet as they did over the LAN previously.

Fundamental Concepts of Networking

Fundamentally, computer networks are simple systems. To build a network, one provides a pathway to move data from one node to another (through electrical signals transmitted over wires or radio signals that travel through the air), gives every node a unique address (so the network "knows" where to deliver packets), and then keeps track of it all (so the network "knows" where to direct each packet of information so it arrives at the correct address).

A consumer network can be set up for less than $100 and has sufficient capacity to provide robust and reliable connections for (perhaps) 10 devices using it at any moment. To create a consumer network environment, one visits an electronics store or office supply store (or web site) and purchases a device that functions as the gateway between the computers and the Internet and routes traffic from the small network to the Internet; the same device assigns addresses to each node, and sends packets to each node within the small network. The nature of the cable that connects the gateways to the circuits outside the building depends on the service purchased from an Internet service provider (ISP); sometimes it is a coaxial cable, sometimes an Ethernet cable, and rarely a telephone cable. Typically, one configures the following on a consumer network as well:

- Wireless access, so that mobile devices can connect to the network;

- Filtering to prevent access to certain sites or to set other rules to limit what can be accessed, when it can be accessed, and on which computers can access the network;

- Firewall to deny unwanted incoming traffic access to the network.

The ease with which one can set up a consumer network can lead technology-savvy consumers (including teachers and school leaders who may be involved with IT management in schools) to misunderstand the task of managing the networks necessary to provide robust and reliable network connections to the hundreds of networked computers and devices in schools. Those require IT professionals to install and manage business or enterprise networks. Consumer devices are designed to be "plug-and-play" systems, so many of the essential functions are preconfigured into the devices as defaults settings and these will work with the defaults settings that are set on consumer devices. As long as nothing is changed, and the number of devices is fewer than about 10, a consumer network will be reliable and robust.

Business class networks are built using network devices with circuits that provide robust and reliable connections to several tens of users. In all but the smallest schools, enterprise networks are necessary to provide sufficient performance. Enterprise networks are very sophisticated and the devices necessary to provide adequate performance on an enterprise network are far more expensive than consumer or business grade devices. Consider, for example, switches; these devices provide additional ports, so devices can share a single connection to the network. On a home network, one might use a switch to allow three desktop computers in a home office to access the Internet through a single cable. On an enterprise network, the system administrator might use a managed switch to connect two new computer rooms full of desktops to the network. The switch (with five ports) for home would cost less than $50, but the enterprise switch (with 48 ports) would cost around $5000. Notice the difference in relative price; consumer ports cost about $10 per port. Enterprise ports cost more than $100 per port!

Networking Concepts and Processes

Ethernet is the dominant type of network installed in schools; it uses cables (consisting of eight strands of copper wires and shielding to prevent electromagnetic fields from interfering with the signal) that connect to ports in computers, switches, and other devices with plastic clips that close circuits throughout the network. Regardless of the size of the network, data rate, addressing, and routing are characteristics that determine how its robustness and reliability.

Data Rate or Bandwidth

Data rate refers to the amount of information that can be transferred over a network in a given time; the term bandwidth is also used to describe data rate. Ever since networks were installed in schools, IT managers have sought to provide broadband access to schools, this term refers to connections to circuits providing the greatest available data rate.

Broadband the term used to describe “large amounts of bandwidth,” but it is a relative term. In 2015, the Federal Communication Commission in the United States of America increased the minimum data rate for connections to be considered broadband to 25 megabits per second (Mbps). In a commonly-cited summary of Internet speeds, Akamai (2017) reported the average connection speed in the United States was 18.7 Mbps. While that is several times faster than the global average (7.2 Mbps), it is much slower than those countries with the fastest average broadband connections. These measurements of data rate are difficult to place in a meaningful context, but the simple observation “the more bandwidth the better the performance of the network” is correct. IT professionals in school enter into contracts with a local Internet service provider (perhaps a telephone company, perhaps a cable television provider) to access a connection to the Internet with a specified bandwidth. The bandwidth provided by the ISP depends on the nature of their circuits and the price the school budgets to pay for the service.

The bandwidth available to users in at a location is limited by the bandwidth of the connection to outside circuits, and bandwidth is a zero-sum quantity. A system administrator might complain, “when those students start streaming music, they are using up all of our bandwidth.” The students are using the finite capacity of the network to transfer information to listen to music, thus it is unavailable for other uses.

All network devices (including the network adapters installed in computers) have a data rating, which reflects that maximum amount of information that can pass through device per unit of time. The first Ethernet networks installed in schools typically used 10Base-T devices which had a maximum data rate of 10 Mbps (megabits per second). It is difficult to understand exactly what that means, but it is important to know those devices were replaced with 100Base-T devices around the turn of the century, and those have largely been replaced with devices rated at 1 Gbps (gigabits per second), and many IT professionals have "future proofed" their networks by upgrading LAN devices to data ratings of 10 Gbps. These new network devices can move data 1000 times more data in a given time than the networks first installed in schools. While an IT manager who has installed 10 Gbps devices can rest assured that the network is likely to be robust and reliable, they know they will replace these devices with devices with greater capacity in the coming years.

The total data rate of a network connection is determined by the device in the network that has the least data rate. Consider a school in which all of the devices were upgraded to provide 1 Gbps data rate, except for the switch that serves the computers in one wing of the school where a 100 Mbps switch remained. In that wing, the greatest possible data rate would be 100 Mbps. Further, if one of the teachers in that wing is using an older computer in which the network interface card (which connects a computer to the network) was rated at 10 Mbps, then that teacher's maximum data rate would be limited by that card. For users in the wing connected through the 100 Mbps switch, an especially that teacher connecting through a 10 Mbps network interface card, the more reliable and robust 1 Gbps network would not be enjoyed.

Factors other than the data rate rating of devices contribute to the actual performance of the devices as well. Many network devices (such as switches) include a small computer and software that helps with sending packets of information to the correct address and other functions. Just like all computers, if those are asked to perform too many functions, they stop working; those frozen processors can reduce data rate to almost zero. The effects of an overloaded gateway can be particularly troublesome as all network traffic flows through it to the Internet. I was once asked to help troubleshoot a network with curious symptoms. Early in the day and late in the day, the network performed adequately for the few adults who were in the building and using the network. Once students arrived and began sending and receiving traffic over the network, it slowed to a crawl and the data rate was about 1% of what was provided by the ISP. The technology coordinator was convinced the problem was due to increased traffic due to computer that was infected with malware, but there was no evidence of a specific computer generating excessive traffic when the symptoms were demonstrated and LAN traffic was unaffected. As it turned out, the network had been configured so that a single switch was responsible for managing much of the network traffic; the result was the switch was unable to handle the traffic and, despite it being rated a 1 Gbps, its effective data rate was a small fraction of maximum. Once network management was shared among several devices, performance returned to normal.

If the maximum bandwidth available from the local ISP is inadequate for the demands of a schools, then the IT professionals must purchase additional lines and divide the network traffic between them; this arrangement provides more robust and reliable availability during those times when network demand is greatest as there is extra bandwidth to handle to extra demands. In recent years, many schools have converted to voice over Internet protocol (VOIP) telephone services. Because of the importance for robust and reliable telephone service to schools, IT professionals will work with the vendors who provide the system to ensure it is served by adequate bandwidth (most often with a connection to the Internet that is separate from the data network). Changes such as these typically require expertise beyond that of the LAN administrator employed by the school, so they hire network engineers to ensure the reconfigured network provides necessary operation during the switch over.

The data rate needed by an organization is heavily affected by the nature of the data being transferred. A text document contains relatively little information, so sending a word processing document over a network consumes little bandwidth; video, on the other hand, contains great amounts of information, thus consumes much bandwidth to transfer. The network demands of a classroom full of students reading Wikipedia pages will be far less than a classroom full of students watching YouTube videos. This explains why many technology coordinators and network administrators will limit access to “broadband hogs” like YouTube by decreasing the bandwidth available to and from the site. They can configure routing and switching to minimize the bandwidth that is available to transmit packets from those sites.

Measuring data rate or connection speed is a very easy task, and it is one of the first steps in troubleshooting a network that is not performing as expected. There are a number of web sites that can be used to perform a speed test for a connection. This is accomplished by the sending files of known size to and from your computer. Time stamps on the packets are used to determine the actual bandwidth of the connection from the user to the site.

Another step in troubleshooting unreliable, and non-robust networks is for an IT system administrator to use packet analyzing software to observe the network traffic in detail. In the vernacular, this is called "network sniffing." Using this software provides one with many details of which nodes are using bandwidth and for which purposes. Computers found to be generating excessive or questionable traffic by analyzing the packets originating from it and passing to it can help IT administrators identify malfunctioning or malware-infected computers. Consider, for example, some Internet games transmit traffic using a specific hypertext transfer protocol port. System administrators can configure the network to not use those ports, thus preventing access to the Internet gaming site from the school network.

Addressing

Each device on a computer network must have a unique address. This is unsurprising as networks operate when information is sent from one node to another, and without a unique address, it would be impossible for packets of information to make it to the correct location. There are two types of addresses (one that never changes and one that varies each time a computer connects to a network), and understanding networking requires knowledge of each.

Every hardware device that connects to a network has a media access control (MAC) address, which is sometimes called the physical address of the device, which is programmed into the hardware when it is manufactured. This address never changes, and it is useful for identifying with precision a computer or device on a network; networks sniffers, of example, will be able to identify the MAC address for every device sending or receiving packets.

Software on a single network device (perhaps a server or router or gateway or unified threat management appliance) has dynamic host configuration protocol (DHCP) operating, and it assigns Internet protocol (IP) addresses to devices attached to the network. The IP address is a temporary address; each time a device connects to a new network it is given an IP address for that session. On its next connection to the network, the device may be assigned the same address or it may be assigned a different one. The DHCP server is configured to have a pool of addresses that can be assigned, when the pool is exhausted, no more devices can be connected.

Into the second decade of the 21st century, Internet addresses were assigned following the rules known as IPv4 (Internet protocol version four), so every Internet node was assigned a quad-dot address which consists of four numbers separated by dots, for example 192.168.1.100. Each IPv4 address consisted of 32 bits, so the Internet consisted of up to 2^{32} (almost 4.3 billion) nodes. Because that number of address was going to be exhausted (which would have stopped the growth of the Internet), computer systems have been configured to use IPv6 (Internet protocol version six), which uses 128 bits to identify an IP address. This expands the number of possible Internet nodes to 2^{128} (3.4×10^{38}); an example of an IP address written in IVv6:

2001:0db8:85a3:0000:0000:8a2e:0370:7334

Almost every network is configured to allow information to be addressed to nodes using either version of the protocol, and IPv4 is still used to configure LAN's.

Internet protocol addresses in either IPv4 or IPv6 are strings of digits, or digits and letters, so they are difficult for humans to remember. So that World Wide Web sites can be accessed via names that are meaningful to humans, domains name servers (DNS) are connected to networks and these convert the universal resource locator (URL) such as http://www.google.com of a web site into its IP address. Occasionally a computer will malfunction in a curious manner; it will appear as if it is connected and some network operations will continue to function, but users cannot open web sites unless one knows the IP. In this case, the technician is likely to say, "It is not resolving addresses," and he or she will track down and resolve DNS problems on the machine.

Gateways which are the devices through which all of the computers on a school LAN connect to the Internet have at least two network adapters. The external adapter is assigned the gateway's IP address on the Internet which is set by the ISP. All traffic requested from the Internet by a computer on the LAN will be sent to that external IP address. The traffic then passes to the circuits that comprise the LAN and the internal adapter of the gateway is set with a static IP address. Software on the gateway differentiates packets of information requested by a LAN IP from those incoming packets that originated from elsewhere and have not been requested. IT security professionals spend much time ensuring incoming data that is not authorized is not allowed to pass into the LAN.

Each network has 255 addresses (in reality, subnets are used to increase the number of addresses, but let's keep it simple in this example). Following the model of an IPv4 quad dot address, one can assign 192.168.0.1 through 192.168.0.255 (the first three sets of digits are always the same on a subnet). These 255 addresses comprise the pool of addresses that can are assigned and managed by the single DHCP server on the network. A system administrator uses up to three options when configuring the DHCP server; two are used on almost every school network, and the third is used less frequently.

First, devices that are always connected to the LAN and always powered on (such as switches, wireless access points, threat management appliances, and printers) are given static IP addresses. This type of IP address is configured in the network settings on the device, and then it is removed from the pool of addresses assigned by the DHCP server. Often, the LAN administrator removes a series of IP addresses from those that can be assigned dynamically, then assigns those to devices necessitating static IP addresses. Devices are assigned static IP addresses when they are likely to receive frequent connections from throughout the network, so both humans and computers benefit from increased performance by always using the same address. In effect, a static IP address establishes a permanent IP address so the IP address and MAC address are both unchanging (until the IP address is changed on the devices by an IT administrator).

Second, devices that are connected intermittently (including desktop and laptop computers, Internet-only notebooks, and mobile devices) are assigned a new address each time it connects by the DHCP server; this is called a dynamic IP address as it frequently changes. The system administrator will typically specify the IP addresses that can be assigned, and once that pool is exhausted, no mode device can connect to the network until the system administrator configures another subnet on the LAN.

A third option, which is less commonly used is to have the DHCP server assign an IP address that is reserved for the device each time it is connected to the network; of course, this method is not really dynamic, but it differs from a static IP address as it is assigned by the DHCP server, and not configured on the device itself. Reserved IP addresses are removed from the pool of dynamically assigned addresses as well. This method is most often used when configuring a static IP addresses requires unfamiliar steps. Some technical schools, for example, connect simulated electrical panels and other industrial interfaces to their networks for training purposes. The computers on the panels cannot be accessed using a familiar graphic user interface, so configuring the static IP address is done by the server rather than configured into the device.

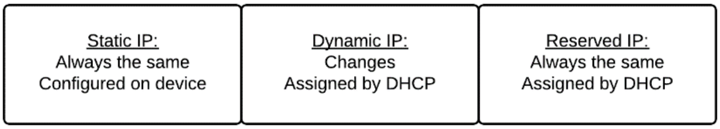

Figure 4.1 Three options for assigning IP addresses

Routing

For networks to function, packets of information must make it to the correct destination. This depends on accurate addressing and also on effective routing. As the name suggests, a routing is the network function in which packets are sent via a route to their destination. Routing occurs between the LAN and the Internet and this is accomplished through a device called a router (or more likely this function is assigned to routing software on a network appliance that serves multiple roles).

Within the LAN, information packets are routed by devices called switches. The unmanaged consumer switch that one can purchase at the office supply store for $50; it works with the default configuration (which cannot be changed) for the small number of devices it connects. The switches on enterprise networks are have sophisticated software that allows them to manage packets sent to and from many more nodes and rules for how packets are sent and received can be configured. This software is one of the reasons enterprise switches cost about ten times the cost of consumer switches per port.

Wireless Networks

The term "wireless" can be applied to two types of IT networks that are commonly accessed by students and teachers. Individuals who carry smartphones and some tablet computers into school buildings connect those devices to the network of cellular phone towers. Those connections depend on the owner having an active account with a provider and the network signal extending throughout the school. Those devices are connected directly to the Internet, and traffic sent to and from those devices does not pass through the school's devices and LAN resources are (generally) unavailable from those networks. These wireless networks are beyond the control of school IT managers.

"Wireless" also describes wireless Ethernet (commonly called wifi) which is the technology used to connect mobile devices (and desktop devices to the LAN with wireless adapters) to the Ethernet network in schools through radio signal rather than Ethernet cables. The phones and tablets students and teachers connect to the cell phone network can also be connected to the wifi in a school. When using those connections (which is typically preferred), the traffic does pass through networks owned by the school. Installing a wifi network requires devices called access points be installed and configured.

Usually access points are connected to the Ethernet network via a cable and given a static IP address, then attached to the ceiling where their health is indicated by LED lights. Inside each access point, there is an antenna that transmits and receives radio waves. To connect to the wireless signal, a computer or mobile device must have a wireless adapter installed and configured; this provides an antenna similar to that installed in the access point.

Access points are configured to broadcast a service set identifier (SSID). Typically, these are given names that are descriptive and a security code is assigned to the SSID. Modern operating systems will notify users that SSID's (or "wireless networks") are available, and the user can select the SSID to which she or he wants to connect. If necessary, the user will be prompted to provide the security code, and those settings can be saved so the device connects automatically when the SSID is available. System administrators can set SSID's so they do not broadcast to users. If a system administrator wants to create an SSID that only technicians use, then it can be hidden and only technicians know the name of the SSID and the security code used to connect it.

An access point can be configured to offer SSID's to devices within its range (typically a few tens of meters depending on building materials and power rating), and the SSID's can provide different capacity. A common configuration is to make three SSID's available on a school network. An "administration" SSID is hidden from users, and is used to connect the devices of system administrators, school administrators, and others who need the most secure connections. A second "teaching and learning" network is used to connect mobile devices owned by the school most of the bandwidth is dedicated to this SSID, and it allows users to authenticate using the servers, and LAN devices (printers, etc.) are all available when connected to this SSID. A third SSID is available for "guests" to connect their own personal mobile devices. Typically, this SSID has limited bandwidth and is does not provide access to LAN resources.

Two coincident factors motivated school IT professional to transition from installing wired Ethernet networks in schools to installing wireless Ethernet networks in schools. First, mobile devices became increasingly used; smartphones, tablet, and Internet-only notebooks are not manufactured with Ethernet ports, so the only option is to connect these through an SSID. Second, advances in the design of wireless devices provided sufficient bandwidth that wireless connections performed as well as wired connections, but the installation costs are a fraction of installing wired networks. The result is that plans for new networks are likely to call for sufficient access points to cover the entire footprint of the school with strong wireless Ethernet signals, and these provide sufficient data rate to provide robust connections.

One of the challenges in establishing a wifi network in a school (or any other building) is ensuring each space is served by a single access point. If there are equally strong singles from two different access points in a classroom (for example), wireless adapters on computers in that room will connect to one, then drop the connection to connect to the other. This process can be repeated continuously and frequently (drops and reconnects that occur every minute are not unusual). During each connection cycle, the network is unusable, so the network will be very unreliable in that classroom.

Network Management

All aspects of enterprise networking require quite specific expertise. Schools employ network professionals to maintain and manage the networks installed and they also retain outside network professionals including engineers and technicians to design and install network upgrades (both hardware and software) and extensions (for example adding wireless capacity).

Planning and Installation

An information technology network is much like other technologies as the expertise needed to design and build it is much more specialized and expensive to than the expertise needed to manage and operate it once it exists. Consider how an IT system in a school is similar to an automobile. Planning and building each requires engineers and designers who have detailed expertise and expensive tools, but they are not needed after the automobile exists. Technicians who keep them operational have lesser (but still considerable) skill and tools. Users can take some minimal steps to keep both operational.

When designing new networks or major upgrades, most technology managers in schools will contract the services of network engineers. Typically, these professionals work for companies that also sell, install, and service the devices included in the engineer's plans; so, installations and upgrades tend to find schools entering into extended contractual relationships for service and repair work on the infrastructure. While these services are very expensive, after school leaders consider the cost of the devices and the potential liabilities of insecure networks, they recognize the value in this expense.

Network installation and upgrade projects are labor-intensive and may cause interruptions in network availability and usually necessitate technicians work throughout the building. To minimize the disruptions caused to teaching and learning, network projects can be scheduled during the times when the school is largely empty of students. The vendors whose engineers plan the installations and upgrades will also have large numbers of technicians available, so projects that require many hours of labor can be accomplished in small lengths of time through many workers.

Engineers design and technicians build IT networks. System administrators operate and manage the networks once they are installed. Serious problems are brought to the attention of the engineers who have more complete knowledge of the system to identify a solution, but most functionality can be sustained by individuals who have been properly trained and how have adequate resources.

A key aspect of planning and installing a network is mapping and documenting the network. IT networks are very interesting systems. From the inside (when connected to the network on a computer that has network sniffing software installed and running), the network addresses of devices can be located with precision and very quickly, but the physical location cannot be easily determined. From the outside (when looking at the physical device), there is no way to know with certainty its network address or the purpose it serves. A good network map will identify both the network address and physical location of devices (the devices will also be labeled with appropriate information). Most network devices (switches, routers, security appliances, access points, printers, and most other devices which are given static IP addresses) include a web server installed on a small computer in the device. By pointing a web browser to the devices' IP address, system administrators can log on to a web page located on the device to monitor its operation, change its configuration, update its software, and otherwise mange its operation. This interface can be used to supplement a network map, but it does not replace network documentation.

Network planning, including mapping, is an important part of managing IT resources is schools, but it is often not given the attention that it needs. IT professionals are typically overworked, so they spend much time addressing technology problems that are very pressing; the work of documenting the network can be left undone. While this is seemingly a necessary approach to resolving technology problems in schools, it can lead to greater difficulties later. When outside agencies need to access the network (perhaps because the system administrator is unavailable) or when the school seeks to document network resources and budget for network replacement, a network map can save many hours of work that is billed at a far greater rate than is earned by an IT professional employed by the school.

Managing Users, Resources, and Data

Once IT infrastructure has been installed, IT professionals hired by the school adjust the configurations of devices installed by the engineers and technicians so the network is secure, robust and reliable. They configure settings to authenticate users; give them access to servers, printers, and other devices; and adjust addressing and security functions as devices are added to and removed from the network. Often these are established before the network is installed (network planning is a vital part of upgrade and replacement projects and finds school IT professional and network engineers meeting for many hours to devise and refine the planned installation).

Accounts are granted permissions according to the users' role in the school and the resources each is authorized to use. The accepted network management practice is to provide individuals who are responsible for managing the school network with two types of accounts; they log on with standard user accounts when simply using the network, but then they log on with an administrator account when they need to change network settings.

In schools, most standard users accounts are assigned to groups such as "school administrators," "teachers," and "students." Student groups are further grouped into organizational units such as "high school students" or "middle school students." With users being assigned to well-planned organizations units, network administrators can quickly and easily deploy changes by applying them to organizational units.

One commonly used practice for managing user accounts on the network is to avoid recording users' passwords. If it becomes necessary for a network administrator to log on as a specific user or to restrict a user from the network, then a system administrator can change the user's password. The user regains control over the account by using a one-time only password from the system administrator, and reset her or his password when first logging on to the system. This step is taken to preserve the user's privacy and to properly account for all the activity using the account. When my password has been changed by the administrator then I am locked out of my account and I cannot be held responsible for changes done under my account. Once I regain control of it, then I am responsible for it.

In addition to managing user's access to the LAN through user accounts, IT administrators can control devices that are connected to the network by adjusting the network configuration. For example, they can send operating system updates to desktop computers, install and update applications, install printers, and set other configurations from one location. Just as user accounts are placed in organizational units to facilitate management of individuals' account who have similar needs, computers can be assigned to organizational units, so (for example) all of the computers in a particular computer room can be adjusted by applying changes to the OU to which the computers belong.

One often-used feature of operating systems connected to network that is used to manage devices is remote access. When this is enabled, an individual who knows the IP address (or host name) of a device can use client software to log on to a computer or server from a different location on the network. This feature allows, for example, technicians at one LAN location (perhaps even in a different building) to take control of a user's computer to troubleshoot problems or observe symptoms. In rural schools that are separated by many miles, but that are connected via a single LAN, this can be very useful as an IT professional can take control of a computer without the need to travel to the site. This increases the efficiency of technicians and minimizes travel expenses.

A well-designed network built with devices of high quality that are properly configured will typically be reliable and robust with little input from IT managers. Of course, networks are systems, so they degrade over time. IT managers in schools spend time and other resources to slow the rate at which networks degrade. One important job in keeping systems operational and secure is updating software, including operating system software, applications, and drivers (which is the software that allows computers to communicate with peripherals such as printers). Sometimes these updates introduce conflicts to the system, so those must be identified and resolved as well.

Occasionally, and despite the best work of IT professions, devices fail in sudden and very noticeable ways; this type of sudden degradation is rarer than the on-going degradation that can make introduce gradual degradation of performance and ultimately failure, but they do happen. System administrators will troubleshoot malfunctioning systems and repair or replace devices that have failed. A well-documented network map will facilitate the work of configuring replacement, so IT managers can restore a robust and reliable network quickly.

Managing the resources and protecting the data on a network also includes ensuring a disaster recovery plan is articulated, familiar to multiple technology and school leaders, and properly followed when (not if, but when) a disaster strikes. A fundamental aspect of disaster recovery is ensuring data and systems are backed-up to servers that are off-site. Many school IT manager contract with services that specialize in backing up the information in organization's LAN's on redundant servers.

Managing network resources also includes investigating proposed changes and upgrades to the system to ensure existing functions are preserved and that new systems are compatible with existing systems. Incompatibilities most often become apparent when operating systems reach the end of life, so they must be replaced. Small schools and early adopters of particular technologies are populations that encounter problematic incompatibilities as well. Small schools tend to purchase student information systems, accounting software, and similar data management applications from publishers whose products are less expensive than others, but that are less likely to be updated. The effect is that these users are locked-in to less than optimal systems by the expense of converting records to new systems.

Network Security

Perhaps the most important function of a school IT administrator is ensuring the network is secure. There are many potential threats to the IT infrastructure installed in a school and the data stored on it, thus network security is multidimensional and necessitates the participation of all members of the IT planning teams. In general, network security is designed to ensure only those who are authorized access systems and data (confidentiality), that the systems and data are accurate and unaltered (integrity), and that those who need access can get it (availability). These three aspects of security are somewhat contradictory; confidentiality and integrity can be ensured by limiting availability, but unfettered availability poses threats to confidentiality and integrity.

Confidentiality is especially important for school IT professionals. The Family Educational Rights and Privacy Act (FERPA) was enacted to ensure sensitive information about students and families are kept confidential. Much of the data about students and families that are stored on school-owned or school-controlled IT systems are covered by FERPA protections; school and technology leaders may be found liable for failing to take reasonable care in protecting this data.

When designing network security measures, IT planners and managers take steps to prevent threats from damaging the system or its data. For example, they limit the individuals who have access to administrator accounts on computers and network devices to those who are trained and authorized, they deploy unified threat management devices which scan network traffic for malware, and they block access to sites know to distribute malware. They also prevent unauthorized incoming network traffic from gaining access to the network.

Securing networks can be a particularly challenging endeavor in those schools where devices owned by students and teachers, and other guests in the school, are allowed to connect their own devices to the network. This is necessary in those schools that have deployed a bring your own device (BYOD) initiative, but there are other situations in which devices not controlled by the school are added to the network. Typically, IT managers provide a "guest SSID" that provides very limited service and others' devices connect to that wireless service.

Network operating systems, and software added to network-connected devices, can monitor and log network traffic and other unusual events; reviewing the logs generated by this software is a regular task for IT professionals in schools. If threats are detected, the IT managers will take steps to remediate damage. This may include, for example, removing a virus infected computer from the network, increasing the settings of threat detection, or restoring data from back-up copies.

It is even possible for IT managers to prevent particular devices from accessing the network. If a student brings a personal laptop to school, for example, and it is known to contain viruses and other threats to the network, then IT managers can use network sniffer software to identify it, then add it to a "black list" on the DHCP server, so whenever that device is prevented from obtaining and IP address, thus switches can neither send no receive data over the network to that computer. (Take a look again at this final paragraph. If you are a teacher or a school administrator who understands what it means, then this chapter has accomplished my goal for you.)

Chapter 5: Web Services

Whereas they once purchased servers that they installed and maintained servers in the schools where they worked, IT managers now purchase computing capacity and storage space on servers owned and operated by others. In this way, computing is similar to electricity generation. Just as we buy electricity that is produced at central locations, we purchase and use computing capacity on servers in a central location. We use the web to access those resources and our web browsers allow us to use those resources and create and manage the information needed for teaching and learning.

The Internet is a collection of computer networks that extends across the globe and even into space as packets of information are transmitted across continents and oceans via satellites. Originally, users of the Internet selected from several protocols or methods of transferring information (for example file transfer protocol or simple mail transfer protocol) or using a computer remotely (for example telnet). The World Wide Web is built upon hypertext transfer protocol, which was added to the collection of Internet protocols early in the 1990's; compared to the other protocols http is a late addition.

In the decades since its inception, the World Wide Web has matured in several ways, and improvements have resulted from both advances in hardware and software of all the computer systems from client through transmission to server and back to client. The computers feature more RAM, more and faster processors, and network adapters with greater bandwidth ratings. The software on the servers that host files and the web browsers on the clients used to access files have also become more efficient and capable of displaying more dynamic and more sophisticated data as well. In addition, the capacity of the circuits over which information packets are transmitted has increased; fiber optic cables are becoming increasingly common and these provide vastly more bandwidth than the plain old telephone circuits used to move data in earlier decades.

The capacity to move vast amounts of information across the globe means efficacious IT managers can use the web to perform many data storage and processing functions that once required local systems. It also means that educators can use web-based tools for many teaching and learning activities that once required local systems. In this chapter I explain the web services that are improving teaching and learning.

Logistic Goal

Efficacious IT managers will articulate a logistic goal such as "Web services will support teaching and learning and the systems will be selected and managed to be easy-to-use and effective." The services that are provided depend on local factors including budgets (some of the web services described in this chapter can be very expensive), the existing network capacity (web services that cannot be reached are worthless), and the needs and expectations of the communities and populations served by the school.

Context for the Goal: The Evolving World Wide Web

At its most basic level, the World Wide Web is a collection of servers; these computers are always powered on and connected to the network. Files on a web server are contained in a directory that is configured to allow outside users to read the contents, and the file is read when a visitor uses a web browser on his to load the file at a particular web address. When visiting a web page, a visitor requests the file be transferred to his or her computer and the web browser uses the directions in that program to display the file on his or her computer. While the basic organization of the World Wide Web has been unchanged since its invention, the languages used to write web pages have matured in the same way the other software and hardware that are the foundations for the web matured.

The first generation of web pages (sometimes called Web 1.0 by those looking back) were simple files. The programs typically displayed only text and low-resolution images. The text was formatted and the location of the images on the pages were determined by tags added in hypertext markup language. Hyperlinks, which connected web pages to other web pages, were also written into the program. Updating a web page included downloading the html file to a local computer, opening the local copy in a text editing program to change the contents of the page including links and formatting tags. The edited files and additional images were then uploaded to the web server and placed in the directory that was replicated in the URL for the page. To see the changes made to edited files, one would open the address, then use the refresh function in the web browser to reload the program; the new page is transferred from the server to the local computer and built in his or her web browser.

Creating content on Web 1.0 was modeled after the print and electronic broadcasting media models that preceded it. Creating and disseminating web content required sufficient capital and expertise to obtain and manage servers and create and format content, so it tended to be controlled by relatively large and wealthy organizations and highly skilled individuals. Early advocates for the World Wide Web in education envisioned an "infinite library" were students and teachers could find vast information written and produced and curated by professional writers, artists, and editors. What has emerged, of course, is something far different.

By the turn of the century, Web 2.0 tools had emerged and were gaining popularity. These allowed users with more limited expertise and fewer resources to create content and publish to the web. Whereas the first generation of creators of content for the web were largely programmers, the Web 2.0 creators needed only to be able to use a word processor.

When comparing Web 1.0 to Web 2.0, three differences are important. First, Web 2.0 allows users or visitors to sites to create content. Whereas the first web pages contained information created by the owner, Web 2.0 sites rely on the users of the site to create the content. This content ranges from simple comments that are added to pages created by others to entire pages designed by the user. Creating content on these sites usually requires one have an account on the site and to comply with the terms of service, but those are easy to meet.

Second, the programs used to create pages on Web 2.0 are much more complex and the programs utilize information stored in databases in a way that Web 1.0 did not. These databases both manage user accounts, so owners of servers can control those who create content on their sites, and the databases are used to manage the files and resources needed to create dynamic and media-rich web sites. For example, with databases a retailer can create a page that displays different products in different colors depending on search results or selections made by the visitor. Web pages created with content stored in databases are often called "mash-ups," and media (especially including video and other interactive elements) can be created on one site and embedded in many pages and sites around the web.

Third, web pages are created so that mouse clicks and other input from users can be used to both create content that is stored in databases and to call programs that are executed on the server or in the web browser. These aspects of Web 2.0 make the contents and the functions of Web 2.0 sites much more dynamic than Web 1.0 sites. Using all of the features on Web 2.0 requires one use a web browser, and that web browser must be updated. Older versions of web browsers cannot be used to create and view much Web 2.0 content.

There are several different web browsers (including Microsoft's Edge which is replacing Internet Explorer, Firefox, Google Chrome, Apple's Safari, and others), and these exist in many versions. The details of how web browsers interact with databases and display data depends on both the exact version of the web browser, the version of the operating system installed on the client computer, as well as which extensions that have been installed on the client. Screen resolutions, installed fonts, and media players are all locally managed options that affect web page appearance and function as well. The result is that web pages are not consistently displayed across all systems and the viewing experience can be very different for different users. This is further complicated by the emergence of mobile computing devices and versions of web browsers for those devices. To accommodate these many variations, most web authors are adopting html 5, a programming language that produces web content that is more consistently displayed on different systems than previous versions. Web authors are also constantly and frequently checking their work on multiple systems as part of their development work.

For many people, the World Wide Web is being replaced by social media sites as the dominant method of accessing online information. Social media comprises a large collection of sites in which the owner of the site provides no content (other than system announcements and advertisements), and the content is primarily viewable by those who are connected in some manner to the individual who posted it. When one visits Facebook, for example, one sees the content produced by her or his friends or advertisements that are based on one's viewing or clicking history. Social media has become the dominant online experience. Greenhow, Sonnevend and Agur (2016) observed,

> Social media are transforming sectors outside of education by changing patterns in personal, commercial, and cultural interaction. These changes offer a window into the future of education, with new means of knowledge production and reception, and new roles for teachers and learners (p. 1).

Some observers have begun to use the term Web 3.0 to differentiate the more participatory web that has emerged as the web matured, but it is unclear how web 3.0 is different from 2.0. What is clear, however, is that many computer applications and functions that were once performed by applications installed on the hard drive of a computer that was sitting on a desk or on a lap are now available as web services. IT professionals choose the best service model to provide these web services; and those decisions are determined by the purpose, the level of expertise they have, and the need to scale the services. For simple file storage, they can choose an infrastructure as service (IaaS) model. If they need to design online applications (that create and use databases, for example), they choose a platform as service (PaaS) model. They can also use software as service (SaaS) which finds them accessing software created on others' platforms. Of course, single services can provide multiple models. G Suite, for example, provide a productivity suite (SaaS model), but also unlimited storage (IaaS model) for educational users.

When using a web service, one points a web browser to a site, logs on, and then has applications running in his or her browser. Web services have replaced productivity applications, media creation tools, and data management tools that were once installed on computer hard drives. While web-based productivity tools tend to have fewer features than the applications install on a computer with a full operating system, they do provide sufficient services for many purposes and the information one creates using a web service can be used to create dynamic web pages for other purposes.

School IT managers provide and maintain multiple web platforms including those for:

- Internal clients to use for teaching and learning (including cloud-based productivity suites and virtual learning environments);

- Internal clients to use for business and information management (including student information systems and document management);

- External audiences to use for interactivity (especially email; but also chat, video chat, and messaging);

- Disseminating information to external audiences (including web sites and social media).

Web services include both those created specifically for educational purposes and audiences (such as student information systems) and also those intended for general audiences (for example social media which I include as web services) that have adapted for educational purposes. Because school IT managers are providing web services for potentially sensitive audiences (children) and that contain potentially sensitive information (about students and other people), they take precautions to ensure the privacy and security of their users and the data for which they are responsible.

Managing Accounts

The information one is able to see, the content one is able to create, and the interactions one is allowed when using any web service depends on the permissions that are assigned to the user. When a web service is first configured, super administrator accounts are created, and individuals who log on with those credentials exert complete control over how the services are to be configured for all of the users within the organization and also make some changes that can affect the operation of the software for all users in the organization. Typically, the super administrator will create other administrator accounts to manage the regular operation of the web service and will use the super administrator account only when changing the configuration of the services.

Many school IT managers find it necessary to support web services from multiple publishers (for example different vendors are likely to provide email, productivity suites, learning management system, student information system, electronic portfolio system, library catalog, and full-text databases for library patrons). Logging on to each system can require a different set of credentials, and users who follow the recommended security practice of having different passwords for each site, are likely to find they forget passwords, so it is necessary to reset passwords frequently.

To minimize the barrier presented by multiple credentials, IT managers can select web services that allow for single-sign on (SSO). A common SSO strategy is to use Google's application program interface (API) to connect web-services to the G Suite domain managed by the school. This allows keys to be shared between web services, so that the credentials on G Suite are used to log on to other systems. In addition to minimizing the number of credentials that users must remember, this scheme provides for centralized management of credentials as changes made to the G Suite profile are reflected in all connected SSO systems.

Regardless of the methods used to manage accounts on different web services, one challenge facing school IT managers is that significant parts of their populations are under 13 years of age. Laws in the United States prevent organizations that provide web services from keeping personal information about young users without explicit permission from the youngster's parent or guardian. For this reason, school IT managers take extraordinary care in vetting the web services that will be used by students and they take extraordinary care in configuring account settings to minimize potential threats to students' information.

Systems for Internal Clients use for Teaching and Learning

Internal clients are those users who belong to the organization and who are subject to the policies and procedures of the organization. In schools, this includes teachers, staff, and students, but also in some situations parents and outside consultants who have the need to access information about the students. School IT managers do provide and support web services that facilitate efficient instruction as well as those that provide for interaction and collaboration for internal clients.

Web Services for Instruction

It has been established that some concepts and skills can be broken down into steps and procedures that are clearly and explicitly presented and practiced, and performance can be clearly measured. Because of these characteristics, they can easily be translated into computer programs. Further, the databases used to store Web 2.0 data can be used to record a wide range of information about students' progress through instructional materials that are on the web.

Designing effective instructional materials can be very expensive as it is time-intensive and requires content expertise, design expertise, and programming expertise; but deploying digital instructional materials is done via the web at minimal marginal cost. Once the materials exist, the cost of having additional users access it are small; IT professionals would say, "they scale well." For these economic reasons, instructional web services used in a school are often provided by organizations external to the school. In the most frequently used model, school leaders subscribe to a service that entitles them to create and manage accounts for students and teachers. Teachers then select the content that will be available to their students, and the content is accessed as part of the school day and also at times outside the school day. A variety of statistics regarding students' use of the system and performance are displayed on a dashboard. In most of these systems; the content, the path and pacing, and the performance are all controlled by algorithms and information programmed into the system.

Instructional web services are available for many content areas, but vendors tend to produce materials for mathematics, computer programming, test preparation, and similar well-known and easy-to-measure content areas. Both commercial entities as well as non-profit organizations create such content. Khan Academy is a non-profit organization that is well-known for the instructional materials it has made available and the tools that can be used to track learners' performance. While many have considered the role of such content in both K-12 education as well as higher education, the role of these organizations in a system of accredited educational institutions has yet to be resolved education (Gebril, 2016; Zengin, 2017). For school IT managers, providing and managing web services for instructional purposes is largely focused on working with teachers to vet the systems they identify as meeting their needs, and that conform to the acceptable technology use policy of the school. They configure the systems for easy access and monitor access to ensure it conforms to the terms of service of the producer. IT professionals then ensure there is sufficient data rate (bandwidth) and the LAN is configured to provide robust access and that web browsers are updated to ensure instructional web services are fully functional.

Cloud Productivity

Productivity suites are collections of computer applications that are used for creating documents and information; a productivity suite will include a word processor, spreadsheet, presentation software, and other applications depending on the tools that have been developed by the publisher and the version of the suite that is being used. For most of the history of desktop computing, Microsoft's Office (with Word, Excel, and PowerPoint among other applications) has been the most popular productivity suite and it is widely used in both schools and businesses. Using Microsoft Office requires one to purchase a license and install the software on a hard drive of the computer upon which one intended to use it. Unless the suite had been installed on the computer that you were using, it was unavailable to you.

Creating word processing documents, presentations, and spreadsheets has been a fundamental purpose of using computers for generations of students and teachers, and these types of files continue to be one of the functions essential to computer users in schools. While Microsoft Office continues to be very widely used, productivity suites that are available as web services and that find users creating word processing, spreadsheet, presentation, and other documents in a web browser are gaining a large share of the educational users. Google's G Suite, formally called Google Application for Education (GAFE), is the most dominant cloud-computing platform; Microsoft's OneDrive and Zoho are other examples, but G Suite is by far the most dominant in the educational market. (Questions about the degree to which Google has monetized public schools and the data about interactions in school are recognized, but have been excluded from consideration here.) All cloud productivity suites operate under similar models. Once they log on, users will see the tools for creating and managing files, files they have created earlier, and even files that have been created by others and have been shared with them in their web browser.

Compared to managing local computing resources, there are several advantages of providing cloud-based productivity. For the students and teachers, cloud-based productivity suites make files and software available on any computer where there is an Internet connection and an up-to-date web browser. Prior to this web service, files were stored locally on computer hard drives or other read only devices (disks of various materials or small circuits of flash memory that plugged into USB ports). While those media were very portable, they were also localized, and without access to the media, there was no access to one's files; forgetting a USB drive meant spending the day without access to one's files. With cloud productivity, files can be accessed from any device with an Internet connection.

Incompatibility between home computers and school computers is another problem that has been resolved with cloud-based productivity suites. In the past, it was not unusual for files that were created on computers at home to be unreadable on computers at school and for files creates at school to be unreadable at home. This was the result of different software and versions of software being installed on the different computers. These problems were avoidable by using universal file formats such as rich text format for word processing files, but this step was often forgotten or ignored. Now that web-based productivity is available to school users, this problem has largely disappeared, at least for productivity files. Files can be read and edited with any computer that is connected to the web and that has an updated web browser installed. This interoperability is perhaps the most useful advantage of adopting cloud-based productivity tools in schools.

Because the files created on cloud-based productivity suites are stored on the web, each file has a unique web address and each file is associated with the account that was used to created it. Owners of these files can share them with other users' accounts. Using this feature, students can collaborate on files and they can share files with teachers so they can edit them, comment on them, or simply view them. For example, a science teacher can share an outline for a project with students so they can view it, and they can click to make their own copy and then the members of a group can be given permission to edit the group's copy of the outline. These files can also be embedded in other places on the web (used as mash-ups), so others can view students work as well. The teacher can then comment on the final version to give feedback.

In addition to advantages of cloud productivity suites for end users, it provides advantage for IT managers. Security, upgrades, backups, and other management tasks fall to the providers of the system. One effect of accepting others' management decisions is that the providers of the system can push changes to users, and those can be implemented without the input or consent of the users (this is not true of all changes, and most changes are announced months in the future, but features that teachers use only occasionally may be changed before teachers can respond). Consider, for example, a teacher who prepared to teach students to write research papers using specific tools in Google Apps for Education. If the managers and engineers of GAFE decided to deprecate or remove one of those tools when upgrading to G Suite, then it will be unavailable to the teacher and her students who now use G Suite; they have no choice but to adapt to the changes made by Google.

For a variety of economic reasons, many providers of cloud productivity suites do make them available at little or no cost to educational populations. As productivity suites do provide educationally relevant (and important) functionality, and because proprietary productivity suites can be very expensive, many schools realize significant cost savings when they adopt cloud productivity.

Virtual Classrooms

Content management systems (CMS) are web content creation and publishing platforms that incorporate many Web 2.0 tools into a single site; users with accounts on the CMS can add, edit, and manage information and media on those parts of the site they have permission to edit. Some content management systems have been designed specifically for managing content and interaction for educational purposes, and these are typically referred to as learning management systems (LMS). Open source LMS platforms have matured to the point where they are easily and inexpensively available and can be installed by school IT managers with modest skills and modest budgets. These tools can be used to support many aspects of teaching and learning in schools (Ackerman, in press).

By providing and supporting an LMS, IT managers in schools enable teachers to offer online sections of courses and they enable blended or hybrid courses in which online activities supplement face-to-face lessons. With an LMS installed, teachers can engage students with a wide range of digital tools from one site. A full service LMS will provide:

- File sharing, so teachers can make templates, word processing files, PDF copies of articles, presentation files, and other files available to students who can access the materials independently;

- Html editors, which support embedded media, so teachers and other course creators can build content pages that incorporate both the content they compose and media from other sources;

- Tests and quizzes that include items (such a multiple-choice questions) that can be graded by the system and those that must be graded by the instructor;

- Assignment drop boxes, so students can submit digital files that are time stamped and grading rubrics, mark-up tools, and other options for providing students with feedback;

- Gradebooks that display both assignments and tests that are part of the LMS as well as columns for off-line work;

- Discussion boards, blogs, journals, wikis and chat rooms that facilitate both asynchronous and synchronous interaction and collaboration.

While these functions are all available on separate platforms, IT managers in schools who implement learning management systems cite several reasons they support the LMS rather than separate participatory web services as the most efficacious method of providing these services. First, IT managers are responsible for supporting the technology that is used for teaching and learning. If teachers are allowed to select the participatory sites they use with students, then IT managers must either learn multiple platforms or they must provide less than adequate support. It is unreasonable to expect technology support professionals to support many and disparate systems, and it is unreasonable to expect students to become facile users of different systems that provide the same functionality. By using a single collection of digital tools, teachers reduce the cognitive load (Sweller, Ayres, & Kalyuga, 2011) that students experience if they must learn to use multiple systems for the same purpose.

Second, using an LMS allows teachers to share grading rubrics, assignments, and other resources across all of the courses taught in a school through templates. Consider a school that offers many sections of a social studies course. Using the capacity to create a course template in an LMS, IT managers can efficiently deploy all of the resources needed by students who enroll in a social studies course. The syllabus, resources, readings, links, assignments, and other features common to all sections of the course can be deployed immediately in the template, then teachers can customize their sites on the LMS for the sections they teach. Further, templates can be used to create courses to allow for more consistent appearance of the site and for consistent tools which can decrease the extraneous cognitive load of using the site and interacting with course materials.

Third, by using the one LMS provided by the school, teachers have more access to support (in using the site) and in troubleshooting and custom configurations than they do when using disparate and separate Web 2.0 tools for teaching and learning. The convenience extends to students as well as they can access materials for all course through a single site and the navigation strategies used in one class will be effective in all other classes.

Fourth, by using an LMS, IT managers and teachers allow data flow between the school's student information system and the LMS. While this frequently requires additional configuration (including programming help from the providers of the systems which is similar to the level of support needed when installing network upgrades), it can allow for automated enrollment management and transfer of grade information. Administrators of an LMS also have access to users' accounts, so they can both manage and troubleshoot accounts and assess and resolve problems. A student who forgets his or her password to a participatory web site may spend many minutes resetting it through email, but the same process on an LMS managed by the school can be completed in far less time. Managing user accounts on an LMS can also be eased by connecting other Web 2.0 accounts to the LMS. For example, using Google applications programing interface (API) and extensions to the LMS, IT professionals can configure an LMS so that G Suite accounts are used to log on.

A final reason IT managers prefer teachers use the LMS they support rather than web sites available to the general population is that participatory web sites are unlikely to allow sufficient control over users' accounts to satisfy local technology policies and procedures, and the terms of use may violate school policy. Using a participatory web site requires one accept the publisher's terms of service (TOS), and those terms may expose students' information to unknown or unforeseen parties. In some cases, teachers use of the participatory web may actually violate the TOS, especially if they are directing students to use the "freemium" version of commercial sites.

Freemium sites allow limited use of sites, generally for personal purposes, and users of the free version see advertisements embedded in the pages they use. Those advertisements may include products inappropriate for students, and requiring students to view advertisements as part of their school work may violate teachers' ethics and school policy.

Once IT managers decide to provide an LMS they have several decisions to make. First, they must decide on the LMS platform to obtain. There are several options, including those from proprietary publishers as well as those developed and supported by open source communities. The functions available are largely the same on each, and how they function depends on the exact version that is installed as well as the features that are enabled and the third-party extensions that are installed.

Second, IT managers must decide a server on which the LMS will be installed. Typically, they select to a) purchase space on a server provided by a company that specializes in hosting the LMS, b) install the LMS on a LAN server, or c) install the LMS on a web hosting service. Each choice has advantages and disadvantages including cost, responsibility for backing-up files and configuring access, and the flexibility of configurations. In general, IT managers can purchase complete LMS management functions and server management, but the cost can be unreasonable for many schools. Managing an LMS and the server on which it is hosted can become a full-time job, however, so those costs can become unreasonable. For IT managers, providing and managing an LMS requires negotiation to ensure it is an efficacious part of the educational technology in the school.

In many organizations and businesses, employees and members use portals that resemble an LMS for many purposes. Employees maintain institutional profiles (which allow them to be paid) and they access work schedules, and receive both organizational training and professional training through online portals. Higher education is increasingly adopting online and hybrid courses, as well. Because portals and online learning are ubiquitous outside of school, many K-12 educators believe experience with an LMS is an essential aspect of middle and high school curriculum to prepare students for the digital landscape of work and school after graduation.

Electronic Portfolios

Whereas the effects of instruction are generally understood to be determined by measuring learners' ability to answer questions in a testing situation after the instruction has concluded, the outcomes of authentic learning (Herrington, Reeves, Oliver, 2014) are generally understood to be demonstrated in products and performances. Artifacts of those products and performances (along with learners' reflection in the importance and meaning of the artifacts) are collected in portfolios. A range of web services can be adopted and adapted for creating electronic portfolios.

As with all web services, IT managers collaborate with educators to make decisions about the web services to be supported for students to make electronic portfolios. Among the important decisions that determine which technologies meet the need are the nature of the artifacts that will document the work (for example audio and video files necessitate different capacity than simply images), the physical and virtual location of the files the be included, and the intended audience for the portfolios. The nature of the students is a further consideration; the needs of high school students preparing their first professional portfolios are far more sophisticated from the needs of elementary students documenting their first project-based learning activities.

In some instances, IT managers will recommend using existing web services as a platform for electronic portfolios; the web site tool in G Suite is a popular choice. Others choose tools that are specifically designed for creating and managing electronic portfolios; Mahara (n.d.) is an example of an open source package that is used to create web-based electronic portfolios. For those students who are graduating and who are adults, IT managers sometimes recommend social networking sites as the appropriate platform for electronic portfolios as students can maintain them once they leave the school and there are already active networks of professionals on those sites that students can join.

Regardless of the web service used for electronic portfolios, they serve several purposes in schools. Eyon, Gambino, and Török (2014) compared the performance of students enrolled in courses that included electronic portfolio with students in courses that did not use that tool. They found evidence that creating an electronic portfolio was positively associated other indicators of student success in college including pass rates of courses, grade point average, and retention rate. They concluded these effects are grounded in the greater levels of reflection and metacognition that are necessary for a portfolio-based program than for one without that experience. Further, they conclude electronic portfolios become a valuable source of information to educators and school leaders as they make decisions regarding programmatic and curriculum changes and improvements.

Web Services for Libraries

As the World Wide Web has matured, many tools have been adopted by and adapted for library services. As the web has become the "place" where patrons access digital research and reference materials, librarians have both embraced digital tools to expand and extended their reach, so—despite the temptation to rely on Google for all of our information needs—libraries continue to play an essential role in schools.

In the 21st century, card catalogues in school libraries first became digital with web interfaces that pointed to databases stored on servers connected to the LAN and located in the school. Today, the databases containing catalog of collections (that can't really be called card catalogs since the cards have bene gone for decades) have been uploaded to the web, and patrons point web browsers to pages where can browse, search, and check the availability of collections.

The nature of the periodicals available to library patrons has changed because of web services as well. School librarians purchase subscriptions that allow patrons to access full-text databases of periodicals. The list of titles that are available depends on the subscription purchased by the librarian, and the subscription may also have some other limits, but in general, library patrons can access effectively infinite collections of peer-reviewed, professional, and popular periodicals from any computer in the world.

Perhaps the most useful tool available to those who use full-text databases, at least from the researcher's point of view, is the automated bibliographic tools. Once a valuable resource has been identified and read (for those of us over a certain age this reading is from a paper copy were have printed and that contains our own hand-written notes), a click of a mouse button can display the full reference in the researcher's choice of several popular style guides. Compiling a reference list requires one to copy (or export) the citation generated by a web service, paste (or import) it into a word processor, then check the format is correct. All aspects of library management and library-based research have been transformed by web services, so librarians are among the most active collaborators with IT managers in schools.

Internal Clients: Information and Business

Schools are information-rich places; teaching and learning necessitates individuals and groups have access to, manipulate, and create information, but running the organization also necessitates administrative and human resource information needs be met. While many of these functions fall outside the focus of this book on teaching and learning, there are several web services that are ancillary to teaching and learning, but that have important implications for teachers.

Student Information Systems

There are a wide range of records kept about students in schools. The list includes demographics (to confirm residency and accurate knowledge of legal guardianship), health records, disciplinary and attendance records, and academic records. These records must be accurate as they are reported to governmental agencies and other schools and organizations, and they may be used as evidence in legal actions. While some student records are still maintained as paper records, most new student records are maintained on student information systems (SIS) that are provided as web service.

Compared to traditional paper-only student information systems, one of the greatest advantages of web-based SIS is the ability of IT managers to query the data contained in the SIS to answer questions and generate reports regarding students' performance or other aspects of students' experiences at school. This has resulted in the emergence of the data analyst as a specialized role within the collection of IT professionals employed in schools. These individuals manage the data in the SIS and write programs to create necessary reports, so the information about schools is more available to leaders and governing bodies than it was when student records were paper.

A web-based SIS can also make information more available to parents and guardians than paper records. When fully configured and deployed, a web-based SIS will allow authorized individuals to create accounts that are given access to view students' information, including grades in individual courses. The online gradebook can be a technology that leads to controversy in communities. While it can be a source of information about performance, many teachers see this as an inappropriate intrusion into the learning community they create within their classrooms.

In schools where both an SIS and an LMS are used, teachers and IT managers typically face a decision about which gradebook to use—either the one in the LMS or the one that is part of the SIS. While parent or observer accounts can be created in LMS's to allow others to see a user's grade, this capacity usually requires additional configuration of the LMS beyond the base installation. Student information systems marketed to K-12 schools have parent or observer accounts as part of the core installation. In some cases, the LMS and the SIS can be connected so that grades entered in the LMS can populate the SIS. A particular concern when configuring the SIS is the Family Educational Rights and Privacy Act (FERPA) which protects students' privacy. When configuring a SIS that is a web service, school IT managers must take steps to ensure that systems are protected from internal and external threat that would expose that data to unauthorized audiences.

Document and Business Management

Schools are social organizations, thus places in which policies and procedures requires information be shared so that tasks can be assigned and resources managed in an equitable and efficient manner. Teachers and others are involved in recommending budget and other decisions, they request purchase be made, and events be scheduled. All of these depend on web-based services that are reliably available and that provide the necessary information in an effective and easy-to-use manner. While these tools fall outside of the collection of tools that directly affect teaching and learning, educators who can manage these aspects of their professional work have more time for their most important work.

Two information management tools for internal audiences that are not specific to teaching and learning, but that have important implications for the technology-using experiences of teachers and their students are the system for scheduling shared resources as well as the system for requesting technology support. Both of those are detailed in "Chapter 6: Technology Support Services."

External Audiences for Interaction

The "I" in IT ostensibly refers to "information," so IT professionals have expertise in operating and managing *information* technologies. The roots of the Internet as a venue for *interaction* among dispersed researchers is well-known. This history, along with the emerging dominance of social media and other messaging tools, suggest the "I" in IT could easily refer to interaction, so IT professional have expertise in operating and managing interaction technology. While "interaction technology" is a term that few would find meaningful, IT managers do recognize that the systems they create and operate are widely used so that faculty, students, and staff can communicate with others within the school and with individuals outside the school. These tools are used by those within the school to initiate contact as well as for outsiders to initiate contact with school employees.

The first tool for technology-mediated interaction to gain widespread use among educators was electronic mail (email); and the number of messages (along with attachments) sent between accounts is astounding. Most messages that arrive at one's inbox in a given day are SPAM (unwanted email). The work of separating the important messages from the noise of the SPAM has led many technology-savvy individuals to adopt other methods of interaction for important messages. Most colleagues know the best way to contact me in a way that will get a quick response is to send me a text message, others know to contact me via FaceBook Messenger, and still others via Twitter or LinkedIn. Despite the decreasing importance of email for professional communication, it is expected that email will continue to be an essential method of interaction for both internal and external communication.

An email inbox points to a location on the Internet; and like all locations on networks, it is unique. Information is sent to this location, then read (or ignored) by the person who has been given permission to see the messages (and send similar messages to other inboxes). Digital records, including those central to web services, are stored in databases, and a requirement of every database is that each record contain a unique identifier. Because they are all different, email addresses serve as unique identifiers in the databases of users for participatory web sites. Also, email address can be used to manage identities, so passwords for participatory web sites can be reset through an email account. For these reasons, email will continue to be a vital, but less important, method for technology-mediated interaction within school populations. In addition, email accounts are likely to be assigned to individual regardless of the degree to which they are used to send and receive messages.

Because email has not been completely replaced as a tool for digital communication, and because many adults choose to separate their professional and personal communication (in some cases they seek to separate multiple professional and personal identities) school IT managers provide email accounts to teachers, staff, and some students. They also tend to articulate expectations regarding how responsive teachers will be to messages received via email. Many parents, vendors, community members, and others expect educators to have access to email accounts and they expect to be able to communicate with educators through email. There are other implications of making email accounts available to members of their communities that school IT managers must recognize and plan to address.

First, school IT managers must decide how to make email accounts available to the public. While it may seem reasonable to publicize email addresses of faculty and staff who are public employees, there are software bots that troll the web searching for that "@" and "." within a word that characterize email addresses. Once these bots find email addresses, they become the target of SPAM and other threats. While this may seem innocuous, the additional messages can place excessive demand on both IT infrastructure and on professionals' time as they seek to manage these messages. Minimizing these demands is particularly important once one recognizes that SPAM is a significant point of entry for viruses and other malware into an organization's LAN.

Second, school populations include those who are under 13 years of age, and their personal information is protected under Children's Internet Protection Act and the Children's Online Protection Act each identify actions IT manager and school leaders in the United States must take to protect this information. Regardless of the laws in any jurisdiction, most school IT managers feel a professional responsibility to protect all students from threats through email. At the same time, educators have a responsibility to give students who are young adults experience using email and managing interaction. Further, some students may have no access to an email account outside of school, and this is an important tool for the transition to post-secondary education or to work.

Third, electronic communications can become evidence in legal proceedings; as a result, school IT managers are expected to archive email and other electronic communications. The length of time such records are maintained depends on the local policy and procedures, but five years is generally regarded as the length of time email and other electronic communications are archived. Such records are kept for the protection of both the sender of messages as well as the recipient of messages. Some school leaders are taking steps to ensure those who contact individuals through school email addresses or other electronic means understand the messages are archived and may be used in legal proceedings.

While email will continue to be a part of school IT used to facilitate interaction within internal audience and between internal and external audiences, the asynchronous nature of these messages interferes with some communication. Chat and video chat are methods of synchronous communication in which information is shared over the web either between individuals or small groups. These tools complement email, and they have common uses in education. Chat is widely used in technology support and sales by vendors. IT technicians who are trying to resolve problems or who are communicating with manufacturers' IT support are likely to be logged on to chat rooms and interacting via typed messages with company representatives. Video chat is a real-time full video link between locations. This is a bandwidth-rich form of interaction, so it tends to be used for very specific activities in which full video is useful.

For many reasons, school IT managers have historically sought to minimize access to chat and video chat. As a result, it was common to find those protocols to be blocked on firewalls and unified threat management appliances protecting school networks in the past. School IT managers can improve interaction with external populations and make these tools available to students and teachers by accommodating requests for chat and video chat in those circumstances in which it is appropriate. They should also be prepared to facilitate both the end capacity and the network resources to use these tools to be robust and reliable in schools.

Disseminating Information

The World Wide Web was originally designed to make it easy for users to access information. For the first decades of the history of the World Wide Web, it was only marginally used by public institutions (including schools) to disseminate information. As the web has matured, it has become available to much larger portions of the population and it is accessed through more types of devices, so there is growing expectation that schools and educators will have an active web presence. Educators make information available on the web so that it can be accessed using diverse devices. As a result, IT managers are supporting educators who disseminate digital information through a variety of platforms. This information includes both policy and procedure announcements and other seemingly mundane (but very important) information such as the school lunch menu and details of students' performances.

In addition to being space for members of the community to learn about their activities, a school web site is often the first place members of the general public go to find out about a school community. Many candidates for job openings will visit school web sites to learn about the school and get a sense of values and beliefs of the community, and these become to focus of candidates' questions to interview committees. Real estate agents visit school web sites to find information for their clients as well. In secondary schools, guidance departments share details regarding college selection and application for students and their families on the web.

Mobile devices, especially smartphones, are becoming the dominant tool for accessing the World Wide Web for many users. Mobile devices differ from computers and laptops in two important ways. First, the web browsers installed on mobile devices have less capacity than the web browsers on computers with full operating systems. Second, the screens on mobile devices are smaller than the screens on desktop computers and laptops. These can affect the way information is displayed on these devices. A growing expectation is that a school web site will be "mobile-friendly," so school IT managers are adopting strategies to build, test, and maintain these sites. In many cases, the CMS used to create the site can be configured to vary how information is displayed when visitors use a mobile web browser.

Increasingly, schools are supplementing their web presence with a social media presence. Social media are the tools on the participatory web that make it extremely easy to publish information, and that information is pushed to specific audiences as well as being available for the general Internet user. Concerns over bullying, distraction, and other problematic uses led many school IT managers to block access to social media sites on school networks. This is proving less effective in minimizing use of social media during school hours that it was previously as students and teachers access social media sites by connecting over the mobile wireless networks and their cell phones, thus by-passing the school network.

Managing an active social media presence does require a web information be posted to multiple platforms. Of course, there are differences in the nature of the information posted on the various social media platforms. By using the embed feature or by creating widgets, social media masters for schools can ensure media posted on social media platform are available in other online spaces as well. Many social media sites allow users' content to be embedded in html pages, and those pages are updated as social media content is created. Some of the social media with educational applications are described below:

- Facebook- This social media platform that boasts billions of users. (Of course, it is easy to count numbers of accounts on Facebook, but is not possible to reliably know how many people are users of Facebook.) Users of Facebook post messages (in text, audio, and video) to their space (the name given to the wall or timeline has changed over Facebook's history); posts are available for "friends" to see and friends may reply or repost or they may tag other users so they see it. One can even stream live video for friends to view. One's profile can be made public or private and groups can be created so that all members use Facebook to communicate.

- Twitter- This microblogging platforms was originally based around 140-chatercter text posts which were seen by followers. Twitter posts can now include more characters and media; hashtags are also used to contribute to wider discussions and to help curate conversations and posts. Two popular uses of Twitter in schools are to update followers on sporting events and to embed Twitter feeds in web pages so that announcements are both sent to followers and posted to the web immediately. Both of these are examples of "live Tweeting" in which information is posted to the social media to make it immediately available to others.

- Instagram- This social media platform is designed to allow users to post pictures. It was acquired by Facebook in 2017, and continues to be widely used.

- Periscope- This is a social media site that is used to live stream video' followers can see what the user's camera is pointed at in real-time (or with a delay of a few seconds). A Periscope feed can also be embedded in a web site, so live streaming can be viewed by any visitors to a web site.

- YouTube- This well-known video site is a social media site that has been part of Google since 2006. Users can upload video (that can be public, unlisted, or private), they can subscribe to others' channels, and they can post comments that appear on the page where a video is displayed.

- Pinterest- When using this social media site, users "pin" stories, sites, images, video, and web sites in order to build collections of related content. This model emerged from the original practice of bookmarking which found users saving the addresses of useful and interesting sites in his or her web browsers. Pinterest is the latest platform for social bookmarking which finds users sharing their bookmarks over the web.

- LinkedIn- This social media site is similar to Facebook, but it tends to be used for professional purposes. While I post pictures of my visits to baseball stadiums and similar events

> on my Facebook page for my tens of friends and family to see, I post short essays and similar items to my LinkedIn profile for my much larger network of professional associates to read.

As the label of the sites makes clear, social media is designed to facilitate interaction, so comments and reactions from other users is a part of life on social networks. Users have little control over the comments others make on their content, and there is little recourse if comments are uncomplimentary, inflammatory, or false. School IT managers can take steps to minimize exposure to unsavory comments. For example, by publishing to Facebook, but not accepting friends, school IT managers can reduce the potential for (but not eliminate) unsavory comments. Further, school leaders can take be active users of social media and model professional interaction and responding in a public manner.

Chapter 6: Technology Support Systems

Sufficient devices, reliable and robust networks, and effective web services all depend on a system being in place and functioning to ensure the hardware and software is maintained, updated, and repaired so it works for teachers and learners. Efficacious IT managers ensure systems are in place to keep IT infrastructure in good repair.

Computers break; they break frequently. Operational computers, laptops, notebooks, and tablets (that connect to reliable and robust networks through which access to effective web services) exist only where there exist systems in place to quickly repair malfunctioning devices (and networks and services). Effective and efficient systems of technology support are multi-dimensional. IT infrastructure must be selected and designed to facilitate effective planning and repair, procedures for communicating when systems need to be repaired as well as communicating that repairs are done must be in place, and the proper personnel must be retained to affect the repairs and those personnel have the necessary training and budgets sufficient to meet their needs.

Logistic Goal

School IT managers will define a logistic goal that is similar to “Malfunctioning IT systems are repaired quickly.” Implicit in this goal is that malfunctioning devices or networks do not interfere with teachers’ ability to plan for technology-rich lessons or with students’ ability to experience those lessons. Also, implicit in this goal is that these systems are supported by the financial resources to supply the people doing this work.

Context for the Logistic Goal

Computers and the information stored on them have become mission-critical (excuse the business jargon) to schools. Without these devices, neither teachers nor students can accomplish what they must to achieve strategic goals, nor can administrative staff ensure the smooth operation of the organization. Whereas "the network going down" or "the computers being updated" represented a minor disruption to previous generations of educators, either of these situations can cause a major disruption today. Just as planning for purchases and installation of devices can no longer be entrusted to IT professionals alone, the design and implementation of support systems ensuring appropriate, proper, and reasonable IT must be a collaborative effort among all school IT managers.

Effective IT Systems

One of the often-overlooked aspects of technology support systems is ensuring that systems are effectively repaired. Effective repairs will result in the system better meeting the needs of teachers and students and the systems being more responsive to their needs. It has been established that IT users in schools are different from the IT users in other organizations, so IT professionals who rely on the clear planning that leads to the effective design of single-purpose systems for business users will find they are less effective for school users. Just like all aspects of managing school IT, selecting the correct systems and designing them for school users is a collaborative endeavor.

In schools where technology support systems are organized into a planning cycle (see figure 6.1) in which technicians affect changes and upgrades to reflect those identified as necessary by teachers, repairs and upgrades appear to be more effective than schools that lack such organization (Ackerman, 2017). In general, IT managers react to situations to increase their efficiency, but they are proactive to ensure changes to systems are more effective.

For technology support to be improved by following this planning cycle, technicians and IT professional must be given responsibility for building solutions in a manner that is secure and compatible with existing technology, and teachers must use the systems in the way the technicians designed them, but decisions regarding the sufficiency of the solutions depend on teachers' perceptions of the solutions, especially when interpreted in light of technology acceptance.

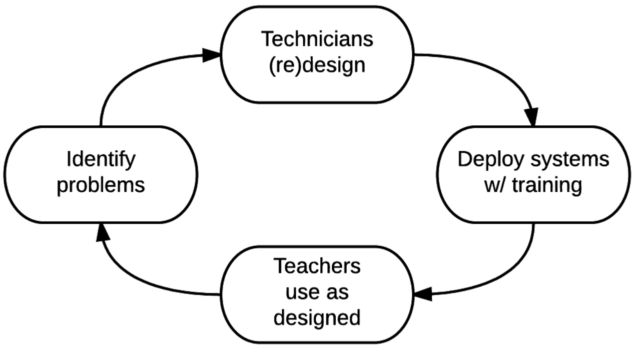

Figure 6.1 Technology planning cycle (adapted from Ackerman, 2017)

The planning cycle provides efficacious IT managers with a procedure to follow to ensure support decisions and actions are fully implemented before they are deemed a success or a failure. When the planning cycle is combined with the unified theory of acceptance and use of technology (UTAUT) (Venktesh et al., 2003), and feedback is given in terms of effort expectancy and performance expectancy, then systems and the repairs made to them are more likely to be judged effective by users.

Communication and Technology Support

Technology support is a process in school that bridges two very clearly bounded groups of people; teachers, students, and other users of IT comprise one group and the IT professionals who affect repairs of IT comprise the other. This book is grounded in the assumption that individuals in these groups understand technology differently; implicit in this assumption is that they will use different language when communicating about IT and that the same language may have different meanings for the groups and for individuals. For these reasons, efficacious IT managers take steps to ensure clear communication between these groups. In the jargon of business management, communication between different groups is called horizontal to capture the movement of information across the different groups (in school IT management these groups include teachers, IT professionals, and school leaders).

Effective communication for technology support is enabled by two web services, one to schedule shared resources and another to manage requests for assistance. Effective communication also depends on transparent and clear procedures when support ends, including when repairs have been affected and when individuals leave a school.

Scheduling Shared Resources

The collection of computer resources available in a school will include those that are too expensive or too infrequently used to justify purchasing them in large numbers. Compared to Internet-only notebooks that can be purchased for relatively low per unit cost and can be used for productivity purposes in many settings, computer rooms along with specialized devices such as large format color printers, 3-D printers, and high-resolution projectors are example of computing resources needed, but in smaller numbers, in schools. Because the devices are in fewer numbers, they must be shared, so efficacious IT managers provide a method whereby teachers can schedule the resources for their students to use.

Effective tools make the schedules public, so they can be viewed in the Internet without logging on or passing through other barriers. (The most effective schedules will be mobile-compatible, so the harried teacher who is finalizing plans for the day can say to a student, “hey, go check the schedule to see if we can print our posters in the computer lab today,” and the student will be able to access and view the schedule on his or her phone.)

Once a student confirms the resource has not been scheduled by another, the teacher can log on to the system to add a reservation, but not edit others’ reservations. Further, each account can have specific permissions so that he or she can reserve only the resources appropriate for the user. For example, only those who have received training in using the 3-D printer are allowed to schedule time on it, or only those teachers whose course necessitate special software can reserve certain computer rooms.

One of the difficulties that is commonly encountered with using scheduling tools in schools is the unusual time increments that characterize the daily schedules in many schools. While many scheduling tools are designed for businesses that are likely to break days into 15-minute increments, schools break days in various chunks, and it is not unusual for different days to be divided into different chunks. Further, some schools have multiple bell schedules, for example students in grades 7 and 8 may follow the "middle school schedule" but the students in 9-12 follow the "high school schedule" in schools enrolling students in grades 7-12. IT managers can increase the use of scheduling tool by making them easy to use, including allowing users to select time blocks on the schedule that correspond to the daily schedule blocks used in the school. All of these can complicate the problem of sharing common computing resources, but none generally are a barrier to sufficient access.

Reporting, Ticketing, and Triage

The web service for managing repair requests that is web-based are often called "ticketing systems," because one submits a "help ticket" that summarizes a problem; the ticket is assigned to someone with the skill and network credentials to fix the problem, and notes regarding steps that are taken are added to the ticket. Once the problem is resolved, the ticket is marked "closed," and the technicians moves on to new assignments.

The value of a fully functioning ticketing system is that it facilitates communications regarding several aspects of managing a large fleet of computer devices:

- Users can report malfunctioning devices with little effort, so the system facilitates communication from users to IT staff. Most IT managers place a link to "create a ticket" in multiple places that computer users frequently visit (the school web page, the LMS, and other portals). In addition, IT managers create an email address, so users can send an email to create a help ticket. Ideally, the ticketing system is part of the collection of tools that use a single sign-on scheme, so the individual who submits the ticket is identified automatically and submitting a ticket does not require on to log on to a different system.

- The technicians can triage malfunctioning devices and decide the best use of their limited resources. While the individual who submits the ticket can usually assign a priority to the repair, the technicians can override those settings, and repairs that will affect a greater number of users or that restore critical systems can be given higher priority.

- A history of each device is maintained. Devices that are troublesome despite repeated repairs are known. Likewise, technicians can track similar problems throughout the fleet. This is particularly helpful when a design or hardware (or software) problem affects the same model; steps taken to resolve a problem on one unit are likely to resolve the same problem on other units. In this point and the previous point, there are examples of how the system facilitated communication within the IT staff.

- Ticketing systems also provide a database on which the inventory can be kept up-to-date. This helps IT professionals understand their fleet and it helps leaders understand the need to plan and budget for replacement devices.

- The total number of repairs performed by technicians and the time they spend on them can be recorded in the ticketing system. This information is used to assess the efficiency and effectiveness of the systems, so that support can be improved by refining systems and by supporting those who support IT users. In this point and the previous point, there are examples of how the system facilitated communication between IT staff and school administrators.

Avoiding Cold Closure

To avoid wasting instructional time preparing to use technology that may or may not be functioning, teachers are likely to avoid those devices that are malfunctioning (or even rumored to be malfunctioning) until they are assured they have been repaired. When a help ticket has been fixed, the technician closes it, then moves on to other duties. While most ticketing systems notify the individual who initiated the case that it has been closed, this can be called a cold closure and it is opposed by a direct closure.

A direct closure occurs when the technician speaks with the individual who reported it and confirms the issue has been resolved. In the ideal situation, direct closure is done in-person, but a telephone call or voice mail are better than cold closure. A teacher who hears, “let me know if it does not work,” will have the confidence to begin using the repaired systems.

Avoiding cold closure helps technicians reduce the occurrence of a troubling situation. If the person reporting the problem either inaccurately describes it or describes a situation with incorrect terminology, then the technician can arrive at the computer and not see what the person who submitted the ticket thought she or he reported. Not seeing the anticipated symptoms, the technician closes the ticket and moves on to other work. The individual who reported the malfunction may return to the machine to discover it still malfunctions because the technician affected no repair or the technicians fixed different symptoms.

While direct closure does reduce technicians’ efficiency, it can increase the effectiveness of repairs and it leads to more accurate repairs being made (which ultimately increases efficiency). Closing this loop of the repair process can be automated by ticketing systems, but many recipients of those messages find them to be confusing rather than informative. Consider the configuration of communication that is set up in many ticketing systems. When the message is entered into the database, a message is generated to tell the individual who reported it “your message has been receive,” and the individual who reported it may find additional messages generated as the repair proceeds. While keeping individuals up-to-date is important, many educators who receive these many messages claim, “they just fill my inbox with unnecessary information.” The excessive messages from the ticketing system can be especially problematic for individuals who use the ticketing system frequently. Because most IT managers insist problems be reported through the ticketing system as it provides important information regarding the fleet of these devices he or she manages, they must take steps to make them easy-to-use and effective.

On-Boarding and Exiting

The term “on-boarding” is used to describe the process of ensuring new employees understand policies and procedures related to the organization. In recent decades, organizations have added IT training to the on-boarding procedures. The details of the school IT systems that must be the focus on on-boarding training have been described previously, and comprehensive on-boarding training decreases the need to support later.

Equally important are the steps taken when an individual leaves a school. Separation can be for a variety of reasons, and efficacious IT managers are prepared to transfer information as is appropriate for those circumstances. In some cases, there are reasons that separation must be immediate; in those cases, school administrators are likely to direct an IT professional to immediately prevent the separated individual from accessing systems, usually by changing the individual's password. Amicable and planned separation is much more common and school IT managers seek to implement exit procedures that ensure individuals can access information they created while associated with the school.

Education is a creative endeavor; students and teachers both create intellectual property as they work. In general, students who are minors own the intellectual property they create (keep that in mind the next time you copy a student's paper to show colleagues). For teachers, the ownership of the intellectual property they create is more complicated. The works teachers create while being paid is "work for hire," thus those are owned by their employer. Works they create while not being paid (during school breaks for example) are not, and in other situations determination of who own teachers' intellectual property can become very complicated. In most cases of amicable separation, school leaders are content to avoid the conflict over ownership of work created for hire by allowing educators to retain a copy of all works he or she created. Educators are content to avoid conflict by avoiding selling of works they created for a specific teaching position without significantly revising the materials, so they represent new works.

To accommodate educators and students who seek to retain the works they created while employed at a school, school IT managers can communicate to teachers recommended methods for archiving and transferring them to their own devices or accounts. With the widespread availability of cloud-based storage, many technicians recommend copying contents of cloud-based folders or LAN folders to cloud storage using accounts owned by the educator or student who is leaving.

The situation can be more complicated when the educator who is leaving has had a role in supervising and evaluating other professionals or when the information containing works created by the educator may pose a threat to one's privacy or violate FERPA regulations. Consider the principal who negotiates with the school board to keep the laptop she or he has been using as part of a retirement or resignation agreement; IT managers have a responsibility to ensure that records of teacher observations and evaluations, copies of letters sent to parents, and other sensitive information is removed from the computer before ownership is transferred to the separated principal.

Strategies to Increase Efficiency

For much of the history of computers in schools, the "timeliness" of repairs was ill-defined and repair deadlines were not critical. When computers were only one or two per classroom and they were only marginally used in the curriculum, a computer being inoperable for a few days or even weeks posed little disruption to students' work. This was largely due to the fact that computers were simply replacing other technologies; for example, the middle school students I visited as an undergraduate replaced graph paper and pencils with computers to create graphs for their science fair projects. Most of the information those students created and consumed information was on paper, students could be engaged even when "the computers are down." As computer rooms arrived, dysfunctional computers posed a greater obstacle to learning, but only if the number of students exceeded the number of operational workstations and as long as needed files were not on malfunctioning computers.

As electronic digital information and interaction has come to dominate, and computers have become vital to how information is accessed, analyzed, and created in diverse classrooms; it has become essential that malfunctioning computers be repaired in a timely manner, with timely being defined in hours or days rather than weeks. Especially in schools were one-to-one initiates are underway, teachers plan their lessons based on the assumption that students will have access to devices, so repairs need to be addressed quickly to minimize the disruption to learning that arise from broken computers. Responsive technology support systems, as a result, are designed to increase the efficiency of technicians so that the time between reporting it and it being resolved is minimal.

IT professionals adopt several strategies to increase their efficiency. Interesting almost all malfunctioning IT can be traced to software; files become corrupt, new devices or new hardware introduce conflicts, and other temporary faults are introduced with updates. Almost all of these software problems can be avoided or resolved with a few strategies. Imaging allows technicians to reset the software on entire systems, freezing prevents changes to the software in systems, and remote access systems allow technicians to log on to computers that are connected to networks from remote locations and then affect software repairs.

Imaging

In the vocabulary of IT technicians, imaging refers to the process of creating a file that contains the copy of a computer hard drive, then sending that to the hard drives of other computers. This strategy is particularly useful in situations where there are a large number of the same model installed in one place.

Imaging occurs in three steps. First, a single computer is configured exactly as it (and the others) needs to be. The operating system and applications are updated, network settings established, printers configured, and old data files are removed and unused applications uninstalled, and any other maintenance tasks completed prior to creating the image.

Second, the computer is restarted using software that bypasses the operating system on the hard drive. This may be done with software installed on a USB disk or that is stored at a network location. Typically, this includes a minimal operating system, so keyboards, network adapters, displays and similar tools function as the software to create and receive the image file is loaded into the random access memory. Third, the software imaging software is used to either create an image or receive an image (overwrite the current hard drive with the contents of a stored image).

There are several complicating factors in creating and using images including:

- Images are model-specific. If a school distributes five different models of laptops to teachers, then the IT staff must manage five images, and they must be sure to deploy the correct image to each model. More recent imaging software is minimizing the need to manage different images for each model, but the IT managers must still be clear about exactly which software titles (including drivers and extensions and configurations) need to be installed on each model.

- It is essential that systems used to make images be thoroughly tested before its images is made and deployed. An error in setting up network printers on the computer used to make the image, for example, can make a whole fleet of computers unable to print if its image is deployed. Technicians must confirm all settings are correct to avoid the need to repeat the process.

- Some reconfiguration of recipient computers may be necessary. Several factors such as the types of software licenses that are on the hard drive used to create the image and the specifies of how devices are named on the network and the methods used to create user profiles determine how much unit-specific configuration is necessary after it receives an image.

- Imaging does irreversibly erase the contents of a hard drive, so data that has not been backup-up is lost. For this reason, technicians ask, "Do you need the data on this computer?" more than once before reimaging a computer.

Typically, a technician will reimage a computer when it is observed to have unusual and difficult-to-troubleshoot symptoms; technicians are frequently heard to say, "Well, that is weird," immediately before deciding to reimage a computer. If a technician suspects a computer has been infected by a virus or other malware, then he or she is likely to reimage it as well. The great advantage of this strategy from the technician's point of view is that the system will be set back to a "known good" configuration with a well-known and standard practice. Further, in the hours that it takes for an image to overwrite the hard drive on a malfunctioning computer, the technician can attend to other repair, because the process completes without further input from the technicians once it is started. Imaging takes a few minutes to initiate, and several minutes to reconfigure unit-specific settings, but when the image is being received, the technician can attend to other work.

In addition to repairing malfunctioning computers, imaging is used for large upgrade and maintenance projects on fleets of computers. A common addition to the "to do" list of technicians over the summer is to "image the computer room" (which may be either desktop or laptop models). This finds a technician creating an image then sending it to all of the computers in the room. This does necessitate large amounts of data being transferred, so it can interfere with network performance when it is underway (which explains the need to do it over the summer). In all uses of imaging, it is a method of resolving software problems with great efficiency.

Freezing

While imaging is a reaction to software changes that have adversely affect the performance of a system, freezing is a strategy that prevents software problems from occurring. A technician installs the application that provides the freezing function and then configures the system exactly as he or she wants it to function. Just like imaging, all updates and applications are installed and the network configuration along with network printers and other peripherals are installed, configured, and tested. Once the configuration is confirmed, the technician calls the freezing software (which is running in the background, unseen by the user) and enters a password which provides access to the controls that can be used to change the state of the computer to "frozen" and restarts the computer. Until it is "unfrozen" by a user who provides the password, then each time the computer is restarted, it returns to the state when it was frozen.

As software to freeze computers has been used, additional features have been added. For example, the directories in which operating systems updates are installed can be left "unfrozen" so that necessary updates are not deleted when the computer is restarted. Also, some user directories can be unfrozen, so that documents created by users can be saved to a frozen computer. While it does prevent many software-induced problems, there are several reasons that IT managers may avoid using this solution:

- Commercial software to freeze computers can be very expensive;

- Unless the version of the software allows for unfrozen directories, it necessitates files be stored on systems other than the local frozen hard drive;

- Unless properly configured, it can remove critical system updates or data;

- As hard drives have approached and exceeded terabytes of storage, the freezing process can lead to noticeable delays in start-up which interfere with the perceived performance of computers in many school settings.

Maintaining Extra Inventory

Especially in those schools in which there is an active one-to-one initiative, some IT managers will purchase extra computers so that dysfunctional computers can be immediately replaced for students. In some school IT shops where there is extra inventory maintained, a student who finds his or her computer malfunctioning for either software or hardware reasons will find a technician who removes the hard drive (containing the operating system, applications, network settings, and the students' data) and installs it in another unit that is identical to the first. This allows the students to return to learning as normal and the technician to troubleshoot the broken devices or return it for repair by the manufacturer after updating the inventory and ticketing system so those records are accurate.

On-Site and Remote Service

The efficiency of IT repairs can be improved by both increasing the access to repairs on-site and increasing the capacity for technicians to affect repairs remotely. While this may appear to so obvious to be superfluous, the strategies and implications for IT managers are quite different.

Assigning trained IT technicians to work in specific school buildings and ensuring the technicians are well-known to students and teachers and having them work in accessible and well-equipped shops does result in repairs being more efficient, but hiring and retaining employees tends to be a very expensive option in schools (and all other organizations). The question is often asked by school leaders, "How many technicians do we need given the size of our fleet?" Many variables (including the age of the machines, the operating system and other applications installed, the nature of the network, the robustness of the design, and the type of use to which the machines are subjected) affect the number of repairs needed in a given time and the complexity of those repairs. Because of these many variables, there is no reliable heuristic for calculating the number of IT technicians that are needed for a fleet. If the load of repairs overwhelms the available technicians on a regular basis, then steps must be taken to improve their capacity to affect repairs; this can be by providing the technicians with more training or better work conditions, or hiring additional technicians to chare the work.

Placing a technician in every school to be the primary source of IT support at that site does improve efficiency of repairs but coincidently it increases dependence on that technician, thus efficiency can actually decrease. When teachers and others depend on the technician, they are unlikely to develop their own troubleshooting skills, so rather than resolving a problem with a few minutes of troubleshooting, productivity (or at least technology-rich productivity) stops while the technician is summoned then arrives to affect the same steps that are within the capacity of other adults. Not only does a technician-dependent teacher demonstrate poor capacity to learn and to problem-solve, but he or she can delay opportunities for learning while waiting for technicians to become available. Further, this can take technicians away from jobs that require their expertise, so both repairs are delayed. For these reasons, when on-site technicians are place in schools, there must be clear rules about what constitutes an IT emergency, and clear expectations of troubleshooting steps and procedures teachers are trained to take and are expected to take prior to seeking assistance.

Technicians also increase efficiency by using remote access tools log on to desktop and laptops computers form any place on the network. Using remote access, they can install and update software, change configurations, troubleshoot, and otherwise manage those workstations over the network. Access to remote access tools is closely managed by IT managers as it can be used for nefarious purposes as well as legitimate troubleshooting and repair. These tools often use protocols and ports that can be exploited by malware, and using these tools can expose the computer systems and the data stored on them to the threat of unauthorized access.

Technology Roles to Fulfill

Information technology professionals comprise a diverse group of professionals and the skills necessary for one specialty within the field are not necessarily transferable to others. Hiring professionals that fulfill the needed role in a school with the appropriate skills necessitates school leaders understand the specialties within IT professions. It is also important for school leaders to accurately and clearly define expectations and that IT professionals can clearly match job descriptions with his or her skills. Accurately describing and filling positions also avoids the waste of paying for skills that are unused or for needing to provide unbudgeted consultants to fill gaps in the knowledge or skill of hired individuals.

Regardless of the positions funded in budgets and the staffing decisions made by school leaders, all of the roles described in this section must be filled by individuals if a technology support system is to be comprehensive and complete. The titles given to the positions that fill these roles vary and the nature of the individual retained to fill the roles are determined by local circumstances, but strategies utilizing full-time employees, part-time employees, short-term employees, and consultants have been effective, and of course, a single individual can play multiple roles. It is rare, however, to find one individual who can fulfill each role with expertise.

Chief Information Officer

It is only recently that educational organizations have adopted the practice of using "c-level" title for those in management positions. Chief financial officers (CFO) manage the business operations of schools and chief academic officers (CAO) are responsible for all aspects of teaching and learning within schools; individuals in these roles report to the chief executive officer (CEO) who typically hold the position of superintendent of schools. Added to the c-level of management in organizations including schools is the chief information officer (CIO) who manages all aspects of the information technology systems within the organization.

Of course, no c-level executive managers work and lead within a vacuum, so—at the highest level—decisions are made to satisfy the needs and limitations of the entire organization, but the c-level manager is then responsible to carry out the implementations those decisions within his or her area of leadership. The role of the

CIO in schools is to advise the other top-level leaders on the nature of the existing technology, the steps necessary to maintain it, and the potential changes that will improve it. Of the many decisions made by the CIO, perhaps none is more important that those involved with installing and upgrading information networks. The individual who fills this role in a school has a level of responsibility similar to those of the other c-level managers and will be qualified by having a comparable level of experience and credentials (including having earned advanced degrees). The CIO will be compensated at a similar level as well.

For much of the history of computers in schools, a single individual was allowed to decide what technology to buy and how to install it. The rationale behind this practice was that those individuals held quite specialized expertise and educators were willing to defer to those with greater expertise. In many cases, that method of decision-making led to technology that was ineffective and even led to conflict as technology decisions were made for technology reasons. As CIO's have been integrated into technology decision-making in schools, there has been a shift towards making technology decisions for teaching and learning reasons. The specific role of the CIO is to advocate for technology that both meets the need of member of the organization and that is reliable and robust. He or she will advocate for rational decisions regarding infrastructure planning, personnel decisions, and support, at the same time he or she ensures technology decisions do not hamper teaching and learning or other organizational goals.

In some colleges and universities, the IT decisions related to teaching and learning are made by the CAO and the CIO builds and maintains the systems deemed necessary by the academic leaders. That model has yet to become wide-spread (especially in K-12 education), but it is anticipated it will become more common.

System Administrators

Once computer networks are installed and configured (usually in consultation with external engineers and technicians), system administrators employed by the school ensure they remain operational and functional. These professionals listen for network problems by both attending to reports of malfunctions from users and by monitoring system logs, and they both resolve problems that are identified and they take steps to ensure continued health of the network.

Among the specific responsibilities of IT system administrators is ensuring users and devices can access network resources, configuring software to backup files and checking those files are being created as expected, upgrading the operating system and driver software on the servers, and otherwise maintaining network hardware and software. They also play an important role in planning for and deploying software and hardware upgrades, and this individual pays particular attention to potential conflicts that may be introduce when networks are changed. In general, if changes are made to a device that manages local area network traffic or that stores data accessed from across the LAN, it is the system administrator who performs the task. This individual will also work closely with technicians to ensure that use devices are properly configured to access the LAN and Internet.

Most system administrators have completed an undergraduate degree in information systems, and they are also likely to hold credentials awarded by IT vendors and professional organizations. In many cases these credentials require effort and understanding that is comparable to graduate certificates and graduate degrees in their field. As a result of their level of training and expertise, system administrators should be compensated at a rate similar to teachers, but their salary should reflect the year-round nature of their work.

Technicians

Technicians are the individuals who have one of the most important roles in IT system operations in schools as they are the face of the IT department to most members of the organization. A technician is likely to spend his or her day troubleshooting and repairing end users' devices such as PC's, laptops, printers, and other peripherals. Because these professionals spend they time interacting with teachers and students, it is essential they have excellent customer service skills and are comfortable interacting with teachers when they are in stressful situations (due to malfunctioning computers) and with frustrated students. On those staffs with multiple technicians, the group can be very interdependent; they collaborate on solving problems and give each other tips. By documenting the repairs they make (ideally in the ticketing system), technicians contribute to the emerging knowledge of the IT systems and they are identifying those that are becoming so dysfunctional as to need replacement. A further role of technicians is to identify network problems that need to be resolved by the network administrator.

The CIO plays an active role in ensuring the technicians who are working in the school receives the professional courtesies and the on-going support they deserve. Many technicians arrive in these positions with an associate degree or similar levels of training that prepare them to understand the systems that will repair, but in many cases, they do not have experience with the specific devices or the specific practices in use in a school, they must receive training as part of their jobs to stay current and to provide on-going support.

Data Specialists

A relatively new specialist to join the IT staff is the data specialist. The need for this specialist arises from both the skills necessary to manage the databases in which demographic, health, behavioral, academic, and other information that is housed regarding students and the increasing demand for data-driven practices. Schools store vast amounts of data in sophisticated databases; while inputting the data is a minor aspect of the work and it requires limited expertise, the expertise necessary to prepare and run queries of the database so that questions regarding correlations and performance can be answered requires much greater expertise. Often this work includes creating scripts that produce reports that are used to support decisions made by school administrators and teachers.

These professionals represent one the first ventures into the field of educational data analytics by schools. In this field, educators seek to apply the methods of data science to predict student needs and performances. It should be noted that these methods have proven informative for some aspects of learning (Macfadyen, 2017), but findings suggest they are not useful in predicting deeper learning (Makani, Durier-Copp, Kiceniuk, & Blandford, 2016).

Customer Service Skills

Regardless of the role or she fills, all IT professionals who work in schools should be expected to demonstrate excellent customer service skills. “Customer service” is not a term commonly associated with education professionals, but they are skills needed for those who are providing technology support. Exactly what is meant by customer service also depends, but—in general—users and managers recognize those who can identify problems and can resolve them quickly and with a pleasant disposition as having good customer service skills.

Individuals identified as demonstrating good customer serviced skills typically have excellent knowledge of the systems or products they are supporting. In addition, they have the capacity to resolve problems in creative and flexible manners, especially when the standard methods prove ineffective. Together, these elements of customer service represent professional knowledge that can be applied efficiently and effectively.

In addition, those with good customer service skills have patient and empathetic personalities. This nature allows them to listen carefully so that they clearly and accurately understand the problem being presented and they recognize its importance. They also avoid the temptation to blame the use for problems with the computer. At the same time, a technician with good customer service skills will see problem solving and troubleshooting as an opportunity to teach the user strategies for avoiding similar problem and resolving them with independence if they arise.

Regardless of the role an IT professional plays in a school, good customer service skills are important. Improving these will increase the efficiency and effectiveness of IT support systems.

CHAPTER 7: DISCOURSE, DESIGN, DATA

IT planning is a necessarily collaborative endeavor in schools. Because it requires those with disparate skills and approaches to collaborate, efficacious IT managers adopt methods they will use to make decisions and they use data upon which they agree. Especially as they begin collaborative planning, school IT managers can benefit from framing their work as discourse that leads to and is informed by design which makes use of research-like data.

Schools are organizations in which leaders are constantly seeking to improve performance. Improvement and performance are difficult concepts to define and quantify, but (like many inexact concepts) we can recognize it when we see it. Improving school IT requires managers to decide what improvements they seek to make, what evidence will indicate success, and how to make them. Improvements can be made by deploying new interventions, refining how existing interventions are instantiated, ceasing those that are ineffective or inefficient, and consolidating others. The strategies used to make these decisions can influence the support the decisions receive in the community and the ultimate success or failure of the decisions from the perspective of the many stakeholders.

For school IT managers, planning is made more complicated than it is for leaders of other organizations because schools are filled with diverse populations. The result of these complications is that problems can be differently defined and framed by different participants. They can also propose, design, and deploy much different solutions; further they assess the same solution very differently. What represents a successful solution to a technology solution to one participant (or one group of participants) can pose a severe barrier to technology by others. To minimize the threats to efficacy, and to promote more effective and efficient decision-making and problem solving, school IT managers can adopt formal processes for the collaborative planning. Following agreed upon methods to define problems, clarify intended improvements, and gather and analyze data help the disparate groups involved in efficacious IT management to make sound decisions.

Data versus Evidence

"Data" has been widely, but imprecisely, used in education for most of the 21st century. Data-driven educators make decisions based on information they have gathered about their students' performance. Ostensibly, this is done in an attempt to adopt the position of a researcher and to ground decisions in objective research, thus give more support for their decisions. Upon closer inspection, however, there is little resemblance between data collection, the data, and the analysis methods used by researchers and those used by most "data-driven educators."

Data-driven educators tend to use data that is conveniently available; this data is almost always scores on a standardized or standards-based tests. These tests include both large scale and high stakes tests and also those administered by teachers in the classroom for diagnostic purposes. The validity and reliability of these tests is rarely questioned; educators who claim to be data-driven accept that the tests accurately measure what the publishers claim. Data-driven educators also tend to seek interesting and telling trends in the data, but rarely do they seek to answer specific questions using their data. Further, they rarely use theory to interpret results; it is assumed that instruction determined the scores and that changes to instruction affected all trends they observe.

Researchers, on the other hand, define the questions they seek to answer and the data methods they will use prior to gathering data; they gather only the data they need, and all data is interpreted in light of theory. Researchers challenge themselves and their peers to justify all assumptions and to demonstrate the validity and reliability of instruments that generate data and they challenge themselves and peers to demonstrate the quality of their data and conclusions; for researchers, conclusions based on invalid or badly (or unethically) collected data must be discarded by credible researchers and managers.

By adopting a stance towards data that more closely resembles research than data-driven decision-making, IT managers tend to base their decisions in data that is more valid and reliable than is commonly used in education. Their decisions are also more likely to be grounded in theory that helps explain the observations. Other benefits of adopting a research-like stance towards data and evidence include:

- More efficient processes as planners use theory to focus efforts on relevant factors and only relevant factors;

- More effective decisions, because multiple reliable and valid data are used;

- More effective interventions, because they focus on locally important factors and there is a clear rationale for actions;

- Assessments and evaluations of interventions are more accurate and more informative for further efforts because evidence is clear and clearly understood.

Research is generally differentiated into two types. Pure research is designed to generate and test theory, which contains ideas about how phenomena work and allows researchers to predict and explain what they observe. Applied research is undertaken to develop useful technologies that leverage the discoveries of pure research; applied research is often called technology development. Scholars who engage in pure research identify and provide evidence for cause and effect relationships; this is typically done through tightly controlled experiments and quantitative data. Scholars and practitioners who engage in applied research or technology development seek to produce efficient and effective tools (see figure 7.1).

Figure 7.1. Continuum of pure and applied research

In 1997, Donald Stokes suggested designing a project to be one type of research does not prevent one from doing the other type, so the dichotomy of pure and applied research is misleading. According to Stokes, many researchers seek to create new knowledge and to solve human problems simultaneously; he suggested replacing the continuum of pure to applied research with a matrix in which one axis is labeled "Do researchers seek new understanding?" and the other is labeled "Do researchers seek to use their discoveries?" By dividing each axis into "yes" and "no" sections, four types of research emerge (see figure 7.2).

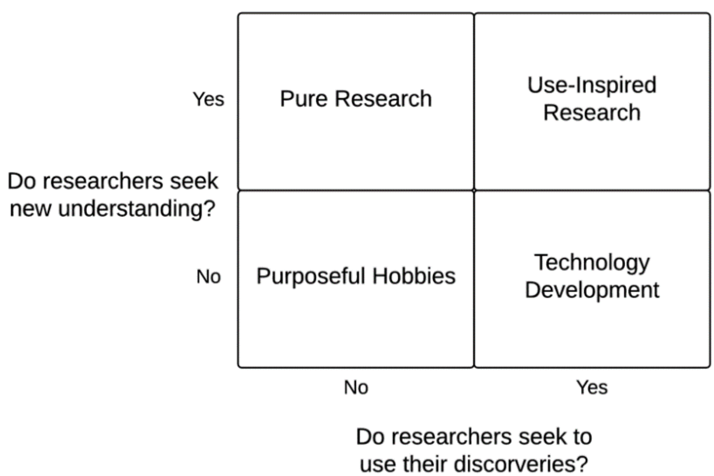

Figure 7.2. Matrix of research activities

Pure and applied research as they were originally conceived do remain on this new matrix. The cognitive scientists who study brain structure and function with little concern for converting their discoveries into interventions are pure researchers whose work may ultimately affect education, but designing interventions is not their primary purpose. The activity of computer programmers who are developing and refining educational games falls into the technology development quadrant. In general, they seek to build systems that are efficient, and they build their systems to leverage the discoveries of cognitive scientists, but their work does not contribute to new understanding.

Stokes' matrix introduces a category of research in which there is neither intent to make new discoveries nor intent to apply any discoveries. While it may seem a null set, there are interesting and fulfilling hobbies such as bird watching that fall into this quadrant. Similar activities are those in which discoveries and applications of knowledge is for personal fulfillment and entertainment. Stokes' matrix also introduces a category of activity in which the researcher intends to both make new discoveries and apply the discoveries; he labeled this "use-inspired research" and referred to it as Pasteur's quadrant. You may recall Louis Pasteur was a 19th century French biologist and he "wanted to understand and to control the microbiological processes he discovered" (Stokes, 1997 p. 79). Pasteur's approach was to both explain the natural science of these diseases and to define interventions that would prevent them. In the same way, IT managers seek to build efficacious systems in their schools and to understand what makes them so.

At the center of use-inspired research is an intervention which is designed to solve a problem. In school IT management, interventions will include many and diverse systems of hardware, software, and procedures and methods to use that hardware and software. Because it is focus of research, interventions can be understood in terms of theory. Theory explains what is observed, and theory predicts what will be observed when systems are changed. Because it is the focus of technology development, interventions are revised so that desired changes are observed. Use-inspired researchers also seek to observe performance in multiple ways. A single measure is not sufficient for the efficacious IT manager whose planning and decision-making is grounded in use-inspired research.

Education and research form a complex situation. Education is a field of active and diverse research; pure research, technology development, action research, and evaluation research all contribute to emerging collection of research. Further, a course in education research is part of almost every graduate program in the field, so many education professionals believe they have a sophisticated capacity to use and even generate research. Despite this, Carr-Chellman and Savoy (2004) observed that inattention to evidence and data in education led to "many innovations being less than acceptable or usable and rarely effectively implemented," but they concluded, "frustration with the lack of relevant useful results have led to more collaborative efforts to design, develop, implement, and benefit from research, processes, and products" (p. 701). Given this observation, it is reasonable to conclude that use-inspired research will improve the collaborative efforts so school IT systems are properly, appropriately, and reasonably designed.

Educational Design Research as a Source of Data

Scholars and practitioners in many fields have developed use-inspired research methods specific to the problems they solve and the interventions they design. Educational design research (McKenny & Reeves, 2012). McKenny & Reeves (2014) captured the dual nature of educational design as a method for designing interventions and a method for generating theory, as they noted it is motivated by "the quest for 'what works' such that it is underpinned by a concern for how, when, and why is evident…." (p. 23). They further describe educational design research as a process that is:

- *Theoretically oriented* as it is both grounded in current and accepted knowledge and it seeks to contribute new knowledge;

- *Interventionist* as it is undertaken to improve products and processes for teaching and learning in classrooms;

- *Collaborative* as the process incorporates expert input from stakeholders who approach the problem from multiple perspectives;

- *Naturalistic* as it both recognizes and explores the complexity of educational processes and it is conducted within the setting where it is practiced (this is opposed to the pure researcher's attempt to isolate and control factors, thus simplifying the setting);

- *Iterative* as each phase is complete only after several cycles of inquiry and discourse.

Projects in educational design research typically comprise three phases (see figure 7.3), and each phase addresses the problem as it is instantiated in the local school and it is either grounded in or contributes to the research or professional literature. For school IT managers, the analysis/ exploration phase of educational design research is focused on understanding the existing problem, how it can be improved, and what will be observed when it is improved. These discussions typically engage the members of the technology planning committee who are the leaders among the IT managers. Design/ construction finds school IT managers designing and redesigning interventions; this phase is most effective when it is grounded in the planning cycle described in Chapter 6. Reflection/ evaluation finds them determining if the solution was successful and also articulating generalizations that can inform the participants' further work and that can be shared with the greater community of school IT managers.

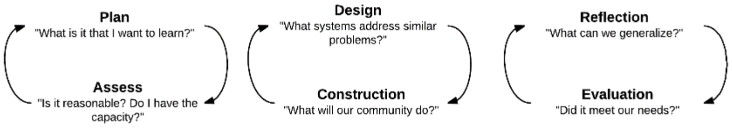

Figure 7.3. Phases of educational design research (adapted from Ackerman, in press)

Defining Improvement

Efficacious IT management depends on all participants maintaining a shared understanding of the problem and the intended improvements; it also depends on discourse so that the participants communicate their perspectives so the systems are properly configured, appropriate for students and teachers, and reasonable given the norms and limits of the school. This can only be accomplished through effective communication, which is threatened by the differences that mark the groups.

Carl Bereiter (2002), an educational psychologist, described discourse as a form of professional conversation through which psychologists can "converse, criticize one another's ideas, suggest questions for further research, and—not least—argue constructively about their differences" (p. 86). This description appears to present discourse as a type of interaction similar to the discussion and debate that characterizes political dialogue and decision making. Bereiter specifies, however, discourse is grounded in data and evidence, so it is a tool for scientific inquiry rather than for political discussions. Bereiter extends the application of discourse to planning for education, and specifically he suggests *progressive discourse* as a method whereby planners can define continuous improvement, implement interventions, and assess the effectiveness of those interventions. In general, progressive discourse is the work of expanding fact to improve conceptual artifacts; this work necessitates a nonsectarian approach to data and decisions.

Planning is the process by which spoken ideas and written language is converted in to actions. Conceptual artifacts are those actions that can be observed in social systems and that are described in the language used to express plans. Progressive discourse depends on planners sharing an understanding of both the language used to capture plans and the actions that will be observed when those plans are realized. Scardamelia and Bereiter (2006) observed progressive discourse depends on participants' "commitment to seek common understanding rather than merely agreement" (p. 102). If IT managers agree on the language they use to define strategic and logistic goals, but not on what they will observe when the logistic goal is achieved, then they do not share a conceptual artifact. Their plans and interventions are likely to be inefficient and ineffective.

In education, we can observe many situations in which different conceptual artifacts are instantiated. There is, for example, a growing interest in using games as a method of motivating students and giving context for deeper understanding. Ke (2016) observed, "A learning game is supposed to provide structured and immersive problem-solving experiences that enable development of both knowledge and a 'way of knowing' to be transferred to situation outside of the original context of gaming or learning" (p. 221). Contained within that conceptual artifact of "learning games" is cognitive activity that causes learners to interact with information and that leads to understanding sufficiently sophisticated that it can be used flexibly. Such games have been found to contribute to effective and motivating learning environments (Wouters & van Oostendorp, 2017).

Ke's conceptual artifact of learning games contrasted with the observation I made while visiting a school and watching students who were completing a computerized test preparation program. After students had correctly answered a certain number of questions, the program launched an arcade-style game that had no connection to the content. It appeared the games were intended to motivate the students and provide a reward for giving correct answers. The principal identified this practice as an example of how his teachers were "integrating educational games into their lessons." The students had discovered the arcade games appeared after a certain number of correct answers and they were "gaming" the system by randomly answering questions by randomly submitting answers in a strategy that led to the games appearing more quickly than if they tried to answer the questions. While the value of determining how to get to the games without answering the questions can be debated, it did not require students to engage with the content. We can reasonably conclude the principal and Ke did not share a conceptual artifact regarding games.

If the principal and Ke were on a technology planning committee together, then we can assume they might both agree that "learning games can be valuable," but their understandings of the experiences that represent learning games would be different. They would agree on language, but not actions, so they would not share a conceptual artifact. The planning committee with Ke and the principal would find it necessary to continue to discuss learning games and resolve their differences so that decisions about what comprise "learning games" were common to the pair.

As progressive discourse proceeds, the participants build greater knowledge from outside sources (new research and new discoveries) and from inside sources (experiences with their own system and community). This knowledge can cause managers to reconsider the definition and realization of a conceptual artifact. When redefining conceptual artifacts, IT managers may be tempted to accept a broader definition, but new and more nuanced conceptual artifacts are generally improvements over the current ones. In this case, the committee may choose to improve the conceptual artifact by differentiating "learning games" from "games for reward" and proceeding with two conceptual artifacts rather than using one definition that is too broadly applied. Improvement of conceptual artifacts occurs when:

- Planners develop a more sophisticated understanding of what they intend in the conceptual artifacts;

- Conceptual artifacts are replaced with more precise ones;

- Managers communicate the conceptual artifacts so more individuals representing more stakeholders share the conceptual artifact;

- IT managers take steps so the conceptual artifacts are implemented with increased efficiency;

- Conceptual artifacts are implemented with greater effectiveness by increasing alignment between conceptual artifact and practice, removing those practices that are the least aligned, or using conceptual artifacts to frame activity in situations where they are not currently used.

Progressive discourse is especially useful during the analysis/ exploration of a problem. It is during this phase of educational design research (McKenny & Reeves, 2012) that IT managers improve their understanding of the problem and the conceptual artifacts that represent solutions. This is a research activity, thus it cannot be undertaken to support a political conclusion, to accommodate economic circumstances, or to confirm a decision been made prior to beginning. Ignoring facts because they appear to violate one's political, religious, economic, or pedagogical sensibilities or because they are contrary to those espoused by another who is more powerful is also inconsistent with the process. Equally inconsistent is selecting evidence so it conforms to preferred conclusions; educational design research and progressive discourse builds knowledge upon incomplete, but improving, evidence that is reasonably and logically analyzed in a manner that researchers approach evidence rather than through political preferences. These may be reasons to accept decisions, but decision-makers have a responsibility to be transparent and to identify the actual reason for making the decision.

Schools, of course, are political organizations and different stakeholders will perceive the value of conceptual artifacts their improvements differently. First, individuals' understanding of the artifacts and acceptance of the values embodied in the conceptual artifacts varies. Because of this, one individual (or groups of individuals) may perceive a change to be an improvement while others perceive the same change to be a degradation; this is unavoidable as it arises from the wicked (Rittel & Weber, 1973) nature of school planning. Second, some participants in the progressive discourse are likely to have a more sophisticated understanding of the conceptual artifacts than others, so they may find it necessary to explain their understanding and build others' understanding of the conceptual artifacts. Further, those with less sophisticated understanding may find their ideas challenged by unfamiliar conceptual artifacts. Third, understanding of and value placed on the conceptual artifacts becomes more precarious when including stakeholders who are most removed from the operation of the organization.

Consider again the example of learning games; it illustrates the implications for various stakeholders when a conceptual artifact improves. If the planning committee decided the arcade-style games in the test preparation violate the accepted conceptual artifact of learning games, the committee may recommend banning arcade-style games in the school. A teacher who uses such games to improve students' speed at recalling math facts may find this "improvement" weakens her instruction. That math teacher may argue for a more precise understanding of arcade-style games, so those she uses are recognized as different from those in the test-preparation program.

If discussions about the role of games in the classroom spilled into the public (which they often do in today's social media-rich landscape), then the continued use of learning games, regardless of their instructional value, might be challenged by those whose oppose game playing in any form by students, especially those stakeholders who do not see students engaged with games in classrooms. This could change political pressures making progressive discourse more difficult.

Designing Interventions

IT managers seek to improve conceptual artifacts through designing interventions. Decisions about which conceptual artifacts to improve and how to improve them are made as IT managers explore/ analyze the local situation. Interventions are designed through iterative processes informed by the technology planning cycle shown in figure 6.1.

There are deep connections and similarities between design and research. Both activities progress through problem setting (understanding the context and nature of the problem), problem framing (to understand possible solutions) and problem solving (taking actions to reach logistic goals). Both design and research find participants understanding phenomena, which affects decisions and actions that are evaluated for improvement of idea or interventions. "Design itself is a process of trying and evaluating multiple ideas. It may build from ideas, or develop concepts and philosophies along the way. In addition, designers, throughout the course of their work, revisit their values and design decisions" (Hokenson, 2012, p. 72). This view of design supports the iterative nature of design/ construction of educational design research. Initial designs are planned and constructed in response to new discoveries made by IT managers; these discoveries can come from the literature or from deeper understanding of the local instances. In terms of progressive discourse, redesign/ reconstruction decisions are made as conceptual artifacts are improved.

One of the challenges that has been recognized in school IT planning is the fact that the expertise necessary to properly and appropriately configure technology is usually not found in the same person. As one who has worked in both the world of educators and the world of information technology professionals, I can confirm that we do not want educators to be responsible for managing IT infrastructure and we do not want IT professionals making decisions about what happens in classrooms. A recurring theme in this book has been the collaborative work that results in efficacious IT management. In design/ construction this collaboration is most important.

School leaders have the authority to mediate decisions about whose recommendations are given priority at any moment. The attentive school leader will be able to ascertain where in the iterative planning cycle any design/ construction activity is and will resolve disputes accordingly. If teachers are complaining about how difficult a system is to use, then the school leader will determine if the proper use has been explained to the teachers and will determine if the complaining teachers are using the technology as it has been designed. If teachers are not using the system as it has been designed, then the school leader will direct teachers to follow instructions. If they are using the system as designed, but it is still inefficient or ineffective, then the school leader will direct the IT professionals to change the configuration of the system to more closely satisfy the teachers. When there is uncertainty about which configuration to direct, school leaders should accommodate teachers and students whenever it is reasonable, as the experiences of students are most critical to the purpose of the school.

Understanding Interventions

School and technology leaders who model their management after educational design research will engage in a process by which they make sense of the interventions that were implemented and the evidence they gathered. This process is intended to accomplish two goals. First, the IT managers seek to evaluate the degree to which the interventions contributed to the school achieving its strategic and logistic goals. Second, IT managers assess their interventions, the evidence they gathered, and the nature of their designs and products; through this inquiry, they articulate generalizations that can be applied to other planning problems. Based on the view of educational design and progressive discourse that has been presented in this chapter, it is more accurate to suggest IT managers evaluate the degree to which strategic and logistic goals are improved than to suggest IT managers evaluate the achievement of goals. Many school IT managers are motivated to analyze/ explore, then design/ construct interventions, to resolve a situation that is perceived to be a problem, so they will continue design/ construction iterations until the interventions are deemed satisfactory, and the problem solved. Even those interventions that are quickly deemed to have solved the problem should be the focus of evaluation/ assessment so the factors that led to the improvements can be articulated and used to inform other decisions and shared with other IT managers.

Compared to those who rely simply on data measured on a single instrument, IT planners who engage in educational design research use more sophisticated evidence to frame their work and this allows them to support more sophisticated generalizations.

They can explain their rationale for the initial design decisions that were made as well as the design decisions made during each iteration; they can explain their conclusions and evaluate their evidence. They also tend to have deeper understanding of how the interventions were instantiated in the local community than other planners, so they can clarify the factors that were relevant for local circumstances and they are more prepared to evaluate the appropriateness of the conceptual artifacts, the cost of improvements, as well as to identify unintended consequences of the interventions. All of this contributes to decisions to maintain or change priorities for continued efforts to improve aspects of technology-rich teaching and learning.

Because their design decisions are grounded in theory and the data they collect are interpreted in light of that theory, IT managers use the theory as a framework to understand what effect their interventions and why those effects occurred. If predictions were not observed, then the situation can be more closely interpreted to either identify problems with the prediction, the evidence collected, or the design and construction of the intervention. It is also possible to identify unforeseen factors that affected a particular intervention, but this can only be done when theory is used to interpret the observations.

Generalizations that appear to be supported by observations can also be reported to the greater community, typically in presentations at conferences or in articles published in periodicals. This reporting of findings increases one's professional knowledge of important practices and it also exposes the work to criticisms and reviews that improve the capacity of the IT manager to continue and that help all participants refine and clarify their knowledge.

The degree to which IT managers' evaluation of interventions in the local community are valid and reliable and the degree to which their generalizations are accepted by the greater professional community is determined by the quality of the evidence they present. Evidence is based in fact. In the vernacular, fact typically means information that is true and accurate. Implicit, also, is the assumption that the fact is objectively defined so every observer will agree on the both reality of the fact and the meaning of the fact. For researchers, facts are grounded in assumptions and established through observation, and observation can refute an idea that was long-thought to be a true fact. For IT managers using educational design research to frame decisions, they seek to recognize assumptions and make decisions based on multiple observations.

Consider the example of a school in which school leaders become aware of evidence that hybrid learning is positively associated with students' course grades (for example Scida & Saury, 2006). They may direct IT managers to install and configure a learning management system (LMS) so teachers can supplement their face-to-face instruction with online activities. Recognizing there is ambiguous evidence of the effectiveness of hybrid and e-learning tools and platforms on learning (Desplaces, Blair, & Salvaggio, 2015), the IT managers who deployed the LMS may be interested in answering the question, "Did use of the LMS affect students' learning?" Data-driven IT managers might simply compare the grades of students in sections that used the LMS to grades of students in sections that did not use the LMS. Those planners are assuming grades in courses really do reflect changes in what a student knows and can do (rather than reflecting teachers' biases for example).

The first step in answering the question would be to ascertain if there was a difference in the grades between the students who used the LMS and those who do not. In adopting a research-like stance towards the data, the IT managers would look for statistically significant differences between the grades of students in sections that used the LMS and those that did not. They may choose a specific course to study to minimize the number of variables that affect their observations. The efficacious IT manager would recognize these differences could be accounted for by many variables in addition to the use of the LMS and effects of the LMS might not appear in this initial comparison. Completely understanding the effects of the LMS of students' learning of Algebra 1 (for example) necessitates further evidence and data; the most reliable and valid evidence includes data from at least three data sources. When studying the LMS, IT managers might answer three questions about the LMS and their students (see figure 7.4).

One relevant measurement might be to compare the performance of different cohorts of students' performance on a common test, such as a final exam given to all Algebra 1 students. Finding statistically significant differences between the scores of students who enrolled in a section in which the LMS was used compared those who enrolled in a section that did not use the LMS

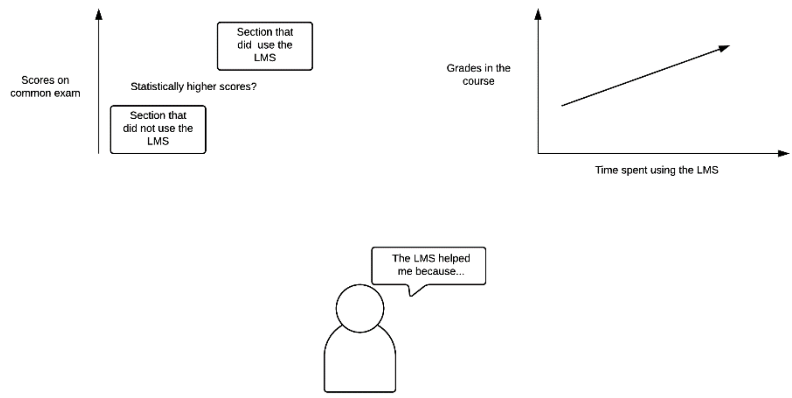

Figure 7.4 Multiple sources of data

might indicate an effect of the LMS rather than an unrecognized effect. To minimize bias in such data collection, steps should be taken to ensure all of the exams were accurately scored and the statistical tests should be performed by those who do not know which group used the LMS (the treatment) and which did not (the control). This is an example of a quasi-experimental design, as the students in this case are unlikely to have been randomly assigned to the sections.

A second observation might be to ascertain if greater use of the LMS is associated with higher scores within sections that used the LMS. The IT managers would have the ability to analyze access logs kept on the LMS that records when individual users log on to the system, and these patterns could be compared to individual students' grades to determine if there is a correlation between use of the LMS and grades. While a positive correlation between access and grades does not necessarily indicate causation, such positive evidence can corroborate other observations.

A third source of evidence to understand the effects of the LMS on student grades might be to interview students to ascertain their experience using the LMS; the qualitative data collected in this way will help explain differences observed (or not observed) in other data. Together, these three sources of evidence given greater insight into the effects of the LMS on students' learning than simply comparing grades.

Rationale for the Effort

Compared to other planning methods and other methods of gathering data and evidence, educational design research may be perceived as necessitating greater time and other resources. There are several advantages of this method, however, that justify its use.

First, IT managers adopt researchers' objectivity and consistency and this reduces the conflict that can arise from the disparate views of the various stakeholders who are interpreting actions and outcomes from different perspectives. That objectivity and consistency also helps conserve the conceptual artifacts that IT planners seek to improve.

Second, students, teachers, and school administrators live and work in a dynamic and evolving environment in which outcomes have multiple causes and an action may have multiple effects. By collecting evidence from multiple sources, IT managers are more likely to understand the interventions as they were experienced by the community. Also, interventions that are developed through iterative processes are more likely to reflect theory. Theory tends to change more slowly than the methods that gain popularity only to be replaced when the next fad gains popularity. Theory-based evidence tends provide a more stable and sustained foundation for interventions that improve how conceptual artifacts are instantiated.

Third, education and technology are domains in which individuals can have seemingly sophisticated experiences, but these methods tend to minimize the threats posed by novices believing they are experts. Many educators have purchased a wireless router, to set up a home network. This can lead them to assume they have expertise in enterprise networking. Technologists are also prone to believe that the years they spent in school give them expert knowledge of teaching and learning. The clear language and diverse perspectives introduced to IT management adopting research methods preserves the complexity of each field while facilitating common understanding.

Fourth, by evaluating and reflecting on the design process as well as the quality of the interventions, IT managers make sense of the interventions they created and can account for their observations. Those conclusions improve their own ability to design similar interventions, contribute to growing institutional knowledge of how the interventions are instantiated in the community, and can support generalizations that can be used by other researchers and by other managers.

CHAPTER 8: UNDERSTANDING CHANGE

The arc of the book has taken us from reasons technology must play a new and unfamiliar role in education through the components of a technology-rich school to the methods whereby IT managers envision, design and deploy, and improve IT systems in schools. Implicit in all of this work is change; IT managers seek to change the tools students and teachers use, the purposes for which they use them, and the manner in which they are managed. In this final chapter, I present ideas about change, and how leaders can manage and promote change within schools.

The literature surrounding organizational change often uses the terms "change" and "innovation" interchangeably. When organizations deploy innovations, the leaders and members adopt new tools, follow new procedures, and are driven to meet new purposes. Scholars and practitioners in the field also recognize change can affect different levels within the organization. Change can be address limited parts of the organizational or the entire system, and it can address small changes or wide-spread changes. The strategies used to implement change depend on the nature of the change leaders seek to make. There are several types of change that leaders recognize:

- *Procedural change* seeks to improve the efficiency of the methods whereby a logistic goal is improved. These are often undertaken in isolation as the inputs into the subsystem responsible for the logistic goal and the outputs from it are unchanged.

- *Systemic change* seeks to improve the effectiveness and efficiency of many procedures at one time. Rather that addressing procedural change as isolated activities, systemic change considers the complex of procedures and especially the interactions between procedures as the important units of change.

- *Transitional change* is recognized as that change which is designed to accomplish new goals. Whereas the same strategic and logistic goals can motivate and drive procedural and systemic changes, transitional change find the procedures and systems changed so that new strategic goals are achieved.

One of the challenges facing leaders who seek to implement changes, especially those that are transitional, is their disruptive nature. Successful organizations have defined structures and procedures and developed culture to meet specific purposes with efficiency and effectiveness. When the purpose of the organization changes, or the previous purposes become obsolete, there is conflict between the previous norms and those needed for the future. Clayton Christensen (1997) observed disruptive changes are those in which qualitatively different goals are defined for the organization, and disruptive change requires structures that are contrary to those that have been effective, and those that have the greatest effects on the structural, human resource, political, and symbolic frames of the organization.

The nature of the change in organizations that efficacious IT managers deem necessary will depend in large part on the existing circumstances and leaders' and members' interpretation of those circumstances. It is anticipated that much of the change suggested in this book will be transitional, especially that in which the Standard Model of educations in overturned. Educators, like all professionals, comprise individuals who are comfortable with change and those who are not comfortable with change. Resisting efforts to change the Standard Model of education and a marginal role for technology are going to be increasingly untenable position for educators. The decisions IT managers make will continue to be a force directing this change.

In their 2010 book *Change*, Chip Heath and Dan Heath, scholars and business leader who study change, attributed resistance to change to three factors. These are observed regardless of the type of change. First, until new practices become habit, people must exert self-control to adopt them; this self-control is necessary to continue using the new practices and avoid reverting to the previous practices. Self-control requires effort, so it is in limited supply. When self-control is exhausted, people return to previous practices.

Second, the greatest motivation for change arises when individuals find an emotional connection to the purpose. The Heaths suggest change arises inside an organization when members become aware of a situation and there is a collective realization that existing practices are contrary to the organization's goals and fixing the problems will result in important changes in the operation or outcomes of the organization.

Third, change can be difficult when the purpose is unclear. They suggest, "what looks like resistance is often a lack of clarity" (Heath & Heath, 2010, p. 17). For Heath and Heath, the path to change is grounded in clarifying the purpose, providing motivation, and creating pathways where by motivation is sustained and action becomes habit and the purpose is achieved.

For IT managers in schools who seek to implement change, Heath and Heath's propose a model of purpose, clarity, and pathway can be complicated by the nature of education and the nature of motivation. For most of the 20th century, leaders assumed individuals within organizations were motivated by pay and other rewards (increasing these were though to increase compliance with new practices) and they were motivated to avoid punishments. While educators are likely to comply with the changes in practice they are directed to make, they are unlikely to internalize the needs and they will revert to previous practices when possible.

In his 2009 book *Drive*, Daniel Pink provided evidence that individuals are motivated by autonomy, mastery, and purpose, so change that is sustained must be based in actions that leverage these aspects of individuals' work. For Pink, autonomy is largely grounded in self-direction; those who perceive they are able to exert control over how they accomplish their goals are more intrinsically motivated than those who have less control. Mastery is the ability of individuals to improve their abilities in a meaningful way and for a meaningful purpose.

Autonomy is a complicated factor in many organizations and professions, including education. While autonomy is a factor that motivates individuals to engage with and adopt innovations, there is evidence that teachers may exert limited autonomy with regards to regarding instructional practices (Range, Pijanowski, Duncan, Scherz, & Hvidston, 2014). Blumenfeld, Kempler, and Krajcik (2006) suggested autonomy is grounded in authority to make decisions and the competence to identify and affect a solution. In many cases, teachers lack the authority to be autonomous and the technology that is the focus of the innovation is unfamiliar and outside their perceived are of expertise.

Further, many teachers have deep personal and emotional commitment to their own education and the practices that marked their entry into the profession and their own teaching. Their understanding of purpose is grounded in these experiences, so teachers who have autonomy may reject the vision and purpose and pathways to change even if they are clearly and reasonably explained. Most math teachers, for example, became math teachers because they found meaning and value in their own math education; they will resist attempts to change the experience of teaching and learning math. The result is a paradox on autonomy; efficacious IT managers need to increase autonomy for teachers to adopt innovative technology and technology-rich pedagogy, but teachers are not used to having autonomy and those who do have it may reject the innovation and seek to subvert it.

(While writing this book, I had a conversation with the manager of a manufacturing facility who indicated workers were no longer allowed to perform their own calculations when configuring machines on the factory floor. Several mistakes had been made, and the company had lost tens of thousands of dollars to resolve each one, so the top-level managers decided that calculations were to be done by engineers using calculators or other simulations of the machines and they tell the operators how to adjust the machines. Math teachers are horrified to hear this story, but the more insightful and forward-thinking take it as motivation to reconsider what they teach and how they teach it. Those are in the minority of teachers who hear this story.)

Whitworth and Benson (2016) suggested three responses by individuals when they perceive a difference between the purposes of the organization and structures of that are deployed. They may accommodate the change and adopt the changes and adapt what they do to reflect the changes. They may relax the definitions (thus creating broader conceptual artifacts) and implement innovations that are nominally different, but that only partially change what they do. Individuals may also subvert change by opposing them or reverting to previously used tools and procedures.

It appears the task of leading change in education is challenging. A leader can expect to encounter disparate and contradictory perceptions of the purpose of school which will lead to disparate and contradictory motivation to engage in the activities necessary to change. Directing educators to adopt new practices or adapt to new practices may result in compliance, but that is contrary to the agency and autonomy the has been shown to result in change in activity.

Educational leaders, including efficacious IT managers, who seek to affect change, can ground their efforts in existing theory related to innovation and change. Leaders who understand organization frames and the nature of innovations and how they are adopted in organizations or communities are more likely to generate changes in practice that are sustained in the schools they lead.

Organizational Frames

Schools, of course, are social organizations; they comprise multiple and diverse individuals who, ostensibly, are working to achieve the same strategic goals through the same logistic goals. The term "ostensibly" is appropriate when describing organizations as they tend to be filled with individuals who different perspectives on the purpose and the work of the organization. Bolman and Deal (2008) are explicit about the difficulty of managing organizations,

> The world of most managers and administrators is a world of messes: complexity, ambiguity, value dilemmas, political pressures, and multiple consistencies. For managers whose images blind them to important parts of the chaotic reality, it is a world of frustration and failure (p. 41).

Bolman and Deal propose four organizational frames to help managers deconstruct what is happening in their organizations and then predict and explain the degree to which innovations or changes are accepted and sustained as well as the reasons they are accepted or rejected. Barriers to innovation, they claim, tend to arise within one of these frames and how a manager responds depends on which of these frames may be problematic. The nature of leadership that is necessary to promote acceptable and sustained innovation and change depends in large part on the frame within which the leader seeks to exert influence. By addressing potential problems, building capacity to address them, and increasing awareness of the problems and solutions within each frame, organizational leaders have a greater chance of being efficacious leaders than those who ignore these frames.

Structural Frame

Organizations exist to accomplish goals; the book is grounded in the assumption that schools exist to ensure students participate in the communication and information landscape that dominates their society so they have experience to continue that participation when they leave the school. (Remember I am a follower of John Dewey, so I believe "education is not preparation for life; education is life itself.")

Within the structural framework leaders seek to implement new structures with innovations; implicit in an innovation is the perception by members of the organization that structures are different from those that characterized their work previously. Innovations may increase efficiency, often after a period of decreased efficiency as the innovation becomes habit. Other innovations are designed to improve performance by more closely aligning the outcomes with the desired outcomes. In some instances, improved performance means accomplishing goals and engaging in activities that were not previously recognized as goals of the organization.

Strategic goals are achieved by achieving logistic goals. Logistic goals, and the strategic goals they support, are achieved through the tools, methods, and procedures that comprise the structural frame including:

- methods for dividing labor (efficacious educational technology depends on different expertise to decide what is appropriate, proper and reasonable);

- controlling activities within groups assigned a responsibility and coordinating between different groups to connect the divisions of labor;

- establishing hierarchy (different individuals should be allowed to override the others when designing educational technology).

Especially in large and diverse organizations in which the logistic goals are only achieved by individuals who have greater expertise than others in the organizations, the division of labor and responsibility is more marked than it is in other organizations. Efficacious IT management is clearly an example of such a situation, so it is helpful for leaders to further deconstruct the structural frame in to components following Mintzberg's (1979) typology:

- *Operating core* which includes those individuals and structures that directly lead to the strategic goal; teachers are the primary personnel in the structural frame in schools and the materials they use are the primary resources in the operating core of schools.

- *Administrative component* which includes those personnel whose role is to manage the operating core and structures they use. In schools, principals and other instructional leaders along with (for example) the system they use to evaluate teachers are among to structures that comprise this component.

- *Techncostructures* includes those components of the structural frame that ensure the system is efficient and effective. In educational technology, this would include the technicians and network administrators along with CIO's who maintain the IT infrastructure.

- *Support systems* include those components of the structures designed to facilitate others' work. The assistant who processes purchase orders for computer hardware is an example of the support systems that comprise the structural frame for educational technology.

Improvements of the structural frame within each component lead to greater efficiency of its operation and the greater alignment with the its effectiveness in achieving those logistic goals that fall under the leadership and control of those with that expertise. In general, when innovations affect the operation of one single component, those leaders and members have greater autonomy in making decisions and deploying innovations.

When decisions and innovations affect more than one component, coordination becomes more important to ensure the innovation is effective from multiple perspectives. Coordination depends in large part on effective horizontal communication. Efficacious IT management in schools depends on the participation of leaders from disparate groups, and they have a role in ensuring members of their organizations understand the rationale for the decision, and members have a responsibility for facilitating horizontal communication of structures within their domain to others.

Consider IT managers who are implementing a new ticketing system to report and track malfunctioning devices. The IT professionals must ensure teachers and school leaders understand the importance of using it (a message that must come from all leaders in the school) and they must ensure the system is easy to use and known to all. It is only in this way that the techncostructure of the ticketing system can help the IT professionals support the operating core of the organization. Consider, also, the configuration of the student information system. How performance is recorded and scores and grades are calculated depends on the SIS being configured so that it reflects the grading policy of the school. This requires coordination between those with different types of expertise and different responsibilities to ensure the intended outcome is realized.

Within the structural frame, procedural changes are common as those within a division of labor attempt to improve their efficiency and effectiveness. These changes are most likely to be accepted and adopted when there is clear alignment between the changes, the logistic goal, and the strategic goals of the organization. For many leaders, this becomes an exercise in backwards design (see figure 8.1). This finds managers defining the logistic goals in collaboration with disparate leaders. In a manner aligned with progressive discourse (Bereiter, 2002), they define both the language of the goal and the observations that will confirm the goal has been met. Within the component of the structural frame, experts will design and improve structures to increase efficiency and effectiveness.

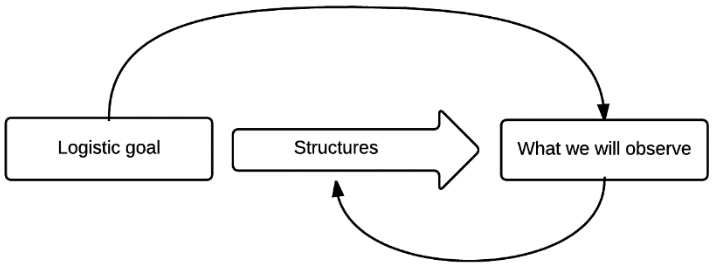

Figure 8.1 Backwards design

Teachers and other school professionals recognize that leaders who are newly hired in schools or central offices often seek to change practices for reasons unrelated to the efficient and effective operation of the structural frame. Consider the school principal who seeks to implement new procedures that have been effective in other schools where she was the principal. While making the changes may improve performance from her perspective or they may make the structure more familiar to her, they may be resisted by teachers and they may result in less effective school operation than the existing procedures.

For technology-rich organizations, understanding change within the structural frame necessitates leaders and members differentiate that change needed to keep current and that change needed for procedural or transformative changes. Technology evolves. To ensure the information ones creates is compatible with that created by others and to ensure IT systems are compatible, they are updated and upgraded. Some of these changes may necessitate procedures and tools be updated simply to maintain the current level of functionality. While these may lead to more efficient use of IT resources, they generally are not perceived to be improvements in the structural frame by leaders or members of organizations.

Human Resource Frame

All actions taken by leaders, and especially those in which they attempt to innovate, have implications for the people who work within the organization. Organizations that are most successful at implementing procedural and transitional changes have employees and members who are fully engaged with the work. They both implement existing procedures as designed and they identify and they communicate methods whereby procedures can be improved; they approach transitional change in the same manner. They connect the purpose to the innovation and improve the pathways between the innovations and the new purpose. The human resource frame addresses those aspects of the organization that affect members' motivation to participate in the changes.

Generations of managers have assumed that individuals would work for pay (or other rewards) or to avoid punishments. While those do work to a limited degree, scholars are beginning to understand the importance of other aspects of work and personality that more accurately predict and explain participation and engagement in change efforts. Efficacious IT managers (and other leaders) now understand the importance of promoting innovations by motivating members and developing human resources in a more complete manner. Bolman and Deal (2008) identified several strategies for fully developing the human resource frame; some of these can be done with the existing human resources while others necessitate changes in staffing.

Management can affect human resources by changing their expectations of members and changing how and why management interacts with members. Examples of these strategies include redesigning structures to align with goals they value and to seek and accept members' feedback in refining structures to improve efficiency. Decisions and actions that members perceive to be the managers supporting their development as competent and contributing members of the organization can improve the human resources frame of organizations. These strategies do include some of the traditional factors thought to motivate, such as promoting from within the organization and increasing salaries. In most educational institutions, many compensation structures are established by negotiated contracts with unions, and many advancement opportunities require additional licenses. Further, teachers who assume leadership roles often find they have less time for their regular duties, so they are less motivated by these strategies than members of other organizations.

Managers can also improve the performance of the human resources frame by articulating a clear vision around supporting employees as valued contributors to the organization. In some cases, the human resources frame can only be improved by changing the individuals who work in the organization. This is especially true when disruptive changes are underway, and the organization cannot continue with those who reject the new purpose of the organization or those who do not have the knowledge, skill, or propensity to adopt and adapt to essential innovations. This is described as adopting a philosophy towards human resources, but in many ways the vision of human resources frame has symbolic implications. This vision also informs hiring decisions, and managers improved the human resources frame by hiring individuals with the personal qualities that are amenable to adopting and accepting change and innovation. One important aspect of hiring IT professionals is also ensuring there is a match between the technology skills of the individual and the expectations of the job.

Argyris and Schön (1996) suggested leaders who adopt a stance towards communication that combines advocacy and inquiry are perceived as effective in implementing change while respecting important aspects of human resources. Through advocacy, leaders attempt to implement change and they are either assertive or passive. Through inquiry, leaders seek to understand others' perspectives on situations. In this model, the leaders who are most effective seek to be integrative, both understanding and assertive; they implement change while accommodating others to the extent possible.

When adopting an integrative stance, leaders do find a role for both the formal and informal participation of the members of the organization in decision-making. This requires leaders to provide sufficient structure that the process does not become a "turf-war" or that irrelevant factors affect decisions. It also requires the leader provide a sufficiently clear goal. When defining goals and processes, however, leaders can become imposing which threatens the participation that is necessary to improve the human resource frame of organizational innovation.

Political Frame

All human organizations are political; they comprise individuals and groups who are largely motivated by self-interest as they advocate the organization support a particular set of decisions and actions. Self-interest is grounded in the different values and beliefs held by individuals as well as different interpretations of information which are affected by those beliefs and values. Political advocacy is necessary as organizations have limited resources, so there are debates and negotiations that influence decision-making about which problems will be solved and which aspects of the structural frame will be improved. This is the situation from which the political frame of organizations innovation arises.

Implicit in the political frame is power and partisanship. Some individuals and the groups to which they belong have greater influence and authority to make decisions than others and partisans are those with lesser power who support the recommendation of others. These, of course, are dynamic characteristics within organizations; individuals or groups can gain or lose power depending on changes in how partisans align their support and other factors including changes in governance. Differences in political power are also consistent with many decision-making processes especially in IT, which finds those who use the systems (and who must find them efficient and effective) and those with expertise in building the systems are different.

Power does arise from various sources including the position one holds; in schools, the superintendent typically has the greatest authority and reports to the publically elected officials who govern the school. Efficacious IT managers will likely find it necessary to defer to the superintendent as the arbiter of political disputes. These leaders also tend to derive power from the ability to control which decisions are made, how the problems are framed, and what solutions are deemed acceptable. In addition to the superintendent, other school leaders derive political power from their offices, but power derived form position tends to be the most tenuous.

Expertise and the capacity to solve the problems faced by the organization (and that are deemed important and unsolved by leaders) is another source of power. Increasingly expertise is determined by the nature and extent of one's professional network as it is a source of strategies and approaches to problems that one has yet to encounter. Reputation is largely grounded in one's expertise and the extent to which others are aware of one's expertise; this awareness is also extended through a wide network.

All leaders and members, including those who hold political power through their office, can extend and expand their political power by negotiating coalitions. An individual who holds expertise that is needed by others gains power and can enter into partisan relationships with others, thus those who are politically less powerful can gain power by forming their relationships. Astute political leaders will attempt to form partisanship alliances with individuals whose sources of power complete those of the leader. Because of the benefits one can gain, the ability to negotiate these partisan relationships is a source of political power that can be improved.

Leaders who seek to promote organizational innovation improve capacity within the political frame by encouraging large coalitions of individuals and group who both support and participate in implementing the changes beyond compliance. Referring to those within organizations who are less powerful due to position, Bolman and Deal (2008) observed, “They accept direction better when they perceive the people in authority to be credible, competent, and sensible” (p. 219). Leaders who have engaged members are more likely to receive accurate and complete feedback from members who are more autonomous.

Political conflict can be a barrier to innovation and even destructive to many aspects of organizations, especially the human resources frame. Efficacious leaders, including IT managers in schools, will recognize the political frame of decision-making, and they will negotiate to leverage collaboration among the stakeholders so that leaders access more complete expertise and those with valuable expertise gain political power. Effective political leaders also develop their own expertise so they are in a better position to evaluate their own expertise and to understand the recommendations of others.

Symbolic Frame

Actions, events, and situations can all have meaning for individuals. In organizations, these meanings determine in large part the emotional and intellectual connections members make to the organization and its purposes and goals. These contribute in an important way to the motivation of members to participate in innovative change. Leaders can develop the symbolic frame to affect how members connect to and identify with the organization, and the extent to which they value and contribute to improving efficiency and efficiency, as well as the collations to which they belong.

The symbolic frame is grounded in the themes that people use to organize ambiguous and unclear situations. Culture and its components such as faith, myths, values, and rituals, all contribute to how the symbolic frame is instantiated. Efficacious leaders who seek to affect the symbolic frame will often craft myths and stories to describe their organizations or their vision for what the organization will become. In many cases these begin as myths, and the organization in fact does not reflect the myth. Over time, as innovations in the structural, human resource, and political frames become aligned with the symbolic vison of the leaders, the vision becomes realized.

A common criticism of leaders who focus on the symbolic frame is that they are “all talk, but no action,” as the symbolic frame is often communicated in grand-sounding, but nebulous, terms. The translation of symbolic language into a clear vision and path is accomplished by defining individuals and the actions of individuals who represent the symbol. This embodiment of the symbols can both demonstrate to members that the vision contained in the symbol is possible and the members can identify with the actions. This allows members to identify a connection to the goals of the innovation which Heath and Heath (2010) observe provides the motivation for change.

Innovations

Everett Rogers’ seminal work the *Diffusion of Innovations* (2003) first appeared in 1962, and he produced multiple versions and editions in the following decades. Throughout the history of the work Rogers sought to understand how innovations (new ways of action or new tools) are communicated (through various channels) over time to the members of a social system. Rogers found the similarities in the characteristics of adopters and in the factors describing the diffusion in a wide range of organizations, industries, and cultures. Scholars continue to use diffusion of innovation as a model for framing data collection and interpreting results. His observations and theory provides several useful frameworks for efficacious IT managers in schools.

The Nature of Innovations

According to Rogers, the rate at which an innovation is adopted by a group is affected by four factors. First, the users must become aware of the innovation and perceive the ideas, tools, or practices as different from those currently in use. In the world dominated by rapid advances in information and other technology, it is easy to assume innovations must be based on things that did not exist previously. Rogers confirms anything that is unfamiliar can be an innovation. How an innovation is perceived is determined by its relative advantage, compatibility with existing practices, complexity, and demonstrability. In general, innovations that diffuse are those that help one improve performance in a meaningful and efficient way, that are easy to use, and that users can try on a limited basis and the results can be shared with others.

Many educators are familiar with seeming cyclic nature of educational reforms and pedagogies advocates claim are innovative. This can lead cynical curmudgeonly teachers—a group which occasionally includes the author when faced with leaders whose credibility, competent, and sensibility is dubious—to remind others "we used to do this years ago."

Second, diffusion of innovation requires communication, and that communication can occur through various types of channels. Mass media, a channel marked by a single person or group communicating the same message to a large audience, and it can be an effective method for introducing innovations to a community. Increasingly, social media and professional learning networks that are maintained and cultivated with digital tools are replacing mass media as a method of communicating innovations. This is one reason those with greater networks have greater political power in organizations that seek to be innovative. The diffusion of innovation typically involves interpersonal communication between dyads or small groups within the social system.

Third, innovations occur within a social system or community comprising members who seek to accomplish a particular goal. Some innovations are designed to accomplish essential aspects of the social system; these can be implemented by authoritarian fit. Others are designed to affect optional aspects of the social system, and these are adopted largely though social influences. Within the social system, there will be leaders whose opinions and perceptions matter to others and there are various types of decisions that are made. Venktash et al. (2003) noted social influences are a factor directly associated with the decision to use technology, thus individuals perceived to be influential are of particular important when leaders seek to diffuse technological innovations. Social systems, we know, comprise structural, human resource, political, and symbolic frames, and how an innovation affects each frame contributes to rate it diffuses and the extent to which it diffuses.

Fourth, the diffusion of innovations is characterized by time. The rate at which individuals within the social system adopt an innovation defines four groups that are considered in the next section. The time necessary for an individual to adopt an innovation depends on the delays between learning of an innovation until the decision is made to adopt it and then to actually implement it. In some situations, individuals may be locked-in to other methods because of investments in time, money, or other resources; or for political or symbolic reasons.

Rogers and others have observed that some innovations are discontinued after they enter a social system. Reasons for discontinuation vary, but replacement by another innovation is common; innovation researchers recognize that an innovative tool, practice, or idea will become traditional practices, which is later replaced by a different innovation. (In education, these innovations often return after a generation of disuse. My grandfather and I used to talk about innovative new science teaching methods that I was using. We found many similarities between those he adopted during his career in the classroom and those I was adopting. We both were active in our professions and had spent summers attending workshops to learn "the innovative new teaching methods.")

Users may discontinue using an innovation when they become disenchanted with it, especially when they do not produce the outcomes promised by advocates. Cuban (1986) noted this was a reason teachers discontinued to use radio, television, and movies as they emerged in the 20th century. Disenchantment can also rise when innovations prove to be unsafe or when other unforeseen and unintended consequences threaten the effectiveness of the innovation.

Stages of Adoption

Once an innovation enters a community, and begins to diffuse, its adoption occurs as the populations accepts it, and this can be explained in a very predictable way. A small number of individuals are responsible for introducing the innovation and those that prove more efficacious, effective, and efficient tend to diffuse through organizations through five different stages. The characteristics of those who adopt an innovation at each stage have also been documented by Roger and others. Two types of lines are used to describe and quantify the diffusion of an innovation, a bell curve illustrates the number of individuals who are in each of five stages of adoption and an s-curve is used to illustrate the part of the population that has adopted the innovation (see figure 8.2).

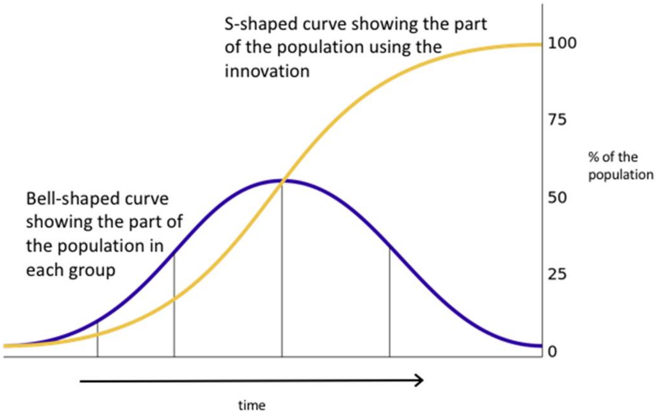

Figure 8.2: Stages of innovation illustrated.

Innovators comprise the first 2.5% of the population of the social system to begin using a new tool or practice or to accept an idea. Individuals in this group tend to be widely connected to others outside the social system or community, thus have greater exposure to new ideas and tools; in the digital world, innovators may be widely dispersed and use digital tools and social networks to maintain their networks. In addition, these individuals tend to have resources that can be dedicated to experimentation with innovations and the individuals are open to taking the risks associated with adopting ineffective or inefficient innovations that do not gain acceptance. This group is illustrated on the far left of figure 8.2.

Early adopters are the next 13.5% of the population to adopt an innovation. Whereas innovators tend to be highly connected outside of an organization or population (thus they are the conduits for an innovation to enter it), early adopters are more highly connected and respected within the organization or population. Innovators seek to identify those who are likely to be early adopters, as those innovations accepted by this group are likely to diffuse more quickly because these individuals exert significant social pressure on others. In addition to vetting the changes introduced by innovators, early adopters become change agents as they become a model for others to follow and they demonstrate the applicability of an innovation.

Members of the *early majority* are the first adopters that are considered followers as they are the first to follow the example of the early adopters. Rogers quotes Alexander Pope who wrote in 1711, “Be not the first by whom the new is tried, nor the last to lay the old aside” to describe this type of user. All adopters proceed from awareness of the innovation through knowledge of the innovation to the decision to adopt it. The early majority tends to take longer than earlier adopters to become aware of an innovation, but once they have knowledge of it from credible early adopters, they tend to make the decision to adopt the innovation.

The second half of the users to adopt an innovation is divided into two groups. For statistical reasons, the *late majority* comprises 34% of the users and the final 16% of the adopters are the late adopters. Once the majority of the population is using an innovation, the late majority adopters yield to increasing expectations that the innovation be used. They also cite practical reasons, including economic factors and decreasing access to traditional tools, when making the decision to adopt an innovation. In many cases, these users adopt an innovation only after the remaining uncertainties over the effectiveness and acceptance of an innovation are removed.

Rogers and others have used the term laggards to describe the *later adopters*. This group tends to retain the traditional tools, practices, and ideas until all other options have been removed. While this group tends to be relatively closed, tending to communicate with others in the group who are later adopters also, the reasons for the later adoption of innovation be this group derive from any factors. Rogers does recognize the tendency in many organizations to blame the individuals who are the last to adopt an innovation, but he criticizes that approach as important factors related to the organization can be understood by studying the rationale given by later adopters for their delay.

Leaders who seek to sustain innovations within their organizations should analyze later adopters and their rationale for not adopting earlier as this can indicate system-wide problems with structure, communication, or implementation that should be resolved. Bolman and Deans’ (2008) structural, human, resources, political and symbolic frames can provide a framework for understand these adoption decisions. In some cases, it is the characteristics of the individuals which led to laggardly adoptions, but in many cases, there are other factors (especially those beyond the control of the later adopters) that affected their knowledge, decisions, or ability to implement an innovation. Understanding these will both help sustain innovations and allow the leaders to more quickly diffuse other innovations.

Innovations within Organization

The diffusion of innovations has been studied in both formal and informal populations. Among the examples that Rogers used often in his books were farmers. Innovations in farming practice tend to diffuse through social systems of farmers who grow similar crops in similar environments, and adoption rates are affected by many both market factors and production factors as well as the degree to which one is locked in. A farmer who has recently purchased a machine that is aligned with a traditional practice is unlikely to discard it for an innovative practice until the new machine has generated sufficient income. Likewise, a school that had purchased a new student information system and has migrated data to it and trained users in using it are unlikely to abandon it for an innovative new system until very compelling reasons are obvious.

Organizations are characterized by specific purposes and it achieves its purpose through specific role that are assigned to members, organizational and authoritarian structures, and both formal and informal rules and practices. As described in the previous section, organizations can be deconstructed into four frames which affect how they accomplish their goals and how it responds to change.

Rogers defined organizational innovativeness in terms of the speed at which an innovation diffuses through an organization. The faster the adoption rate, the more innovative the organization. He also found eight factors that affect organizations innovativeness; six are positively associated and two are inversely associated.

Given that autonomy is known to be a factor continuing to member's motivation and participation to adopt innovation, it is unsurprising to learn Rogers finds *centralize management* and high levels of *formalized processes* to be negatively associated with the adoption of innovations within organizations. In addition to being an obstacle to the entry of innovations into an organization, centralized management and formalized processes slow adoption as the single entities responsible for approving changes become a bottleneck where the diffusion of innovations slow.

It is perhaps not surprising that *leaders' attitudes towards change* is positively associated with organizations innovation. Those leaders who are more accepting of innovations are more likely to both seek out innovations, become an active advocate for them, and make decisions and delegate authority in a manner that that contributes to the more rapid diffusion of innovations within the organization. Further, members of the organization who have a positive attitude towards change will find fewer reasons to avoid innovations, thus they quickly adopt them which increases organizational innovativeness. Hiring such individuals (and providing mentors to those who are not) becomes a human resources strategy that can increase the diffusion of innovations.

Interconnectedness and *openness* are variations on the same characteristic; each determines the availability and use of channels of communication. Organizations with connections to the outside are open and those with deep interpersonal connections within the organization are interconnected. Both of these contribute to the communication that is essential to the diffusion of innovations as they are more likely to enter an open organization and diffuse through an interconnected one.

Slack is a measure of the resources within an organization that are not committed to other purposes. Financial, personnel, and other resources that can be used to support innovation, thus increasing the capacity for diffusion of innovations and the development of expertise.

Complexity is in interesting factor. Organizations comprising individuals with greater expertise and knowledge in their area tend to be more complex, and innovations tend to enter those organizations through those individuals. In general, greater complexity is associated with greater organizational innovation. *Size* is also an interesting factor associated with organizations innovativeness. Larger and more complex organizations tend to have greater formalized procedures and centralized structures which decrease innovation. Despite this, Rogers found larger organizations to be more innovative, others (for example Laforet, 2016) have found small organizations to be more innovative.

Even in those organizations in which the characteristics positively associated with the diffusion of innovations are observed, leaders tend to follow a consistent procedure when selecting those innovations to pursue and implementing innovations, and five processes characterize this work:

- Agenda-setting;
- Matching;
- Restructuring;
- Clarifying;
- Routinizing.

As listed, these represent the chronological order in which innovations diffusion through organizational practice, but in the most innovative organizations, these processes tend to be blurred and the progression is not always linear.

Agenda-setting is the process of identifying a problem within and organization and determining that it is going to receive the attention of leaders and a solution will be designed and implemented. Because organizations have a purpose which is embodied in the strategic goal, the problems that are solved through innovation are directly related to the degree to which the purpose of met (or not met). Problems typically emerge from the organization's purpose and may be defined so the organization gains competitive advantage, addresses an unmet need among clients, or otherwise expands its reach or improves its performance. Implicit in the agenda setting is that some aspect of the organization will be changed. In most organizations, agenda-setting occurs within the political frame, and only those situations recognized by the most powerful leaders receive the attention or members or the financial resources of the organization.

Matching is undertaken to ensure the innovation meets the needs of the organization. In some cases, new ideas or new tools are produced by manufacturers or publishers and incorporating those into the organization becomes a priority, despite the fact the need did not exist before the innovation was produced by others. Mobile phones are the quintessential example; until they were invented and became used by a critical mass of individuals, the devices did not focus innovation. Now, mobile devices have led to many innovations in products, processes, and services. Innovators, the first 2.5 % of a population to adopt it, play an important role in finding and introducing innovations to organizations and finding those that may match problems identified in agenda setting.

Restructuring is the process whereby the innovation is customized to fit the needs and the existing structures (and human resources, politics, and symbolism) of the organization. In some instances, this requires modifying the innovation so the tool, practice, or idea more closely aligns with the existing organization; and in other instances, it requires the organization adapt to reflect the capacity of the innovation. Through either approach, restructuring assures a match between the innovation and the operation of the organization.

No matter how careful and attentive the restructuring process is, there will be gaps the in the implementation of the innovation. Anticipated improvements will not be realized and unexpected consequences will emerge, so leaders will support the clarification of innovation, and this also includes both adapting the organization to the innovation and adapting the innovation to the organization.

Once innovations are tuned to the needs and structures of the organization, they become a part of the routine. Once completely routinized, innovations are no longer innovations and they become the traditional practice and tools that are replaced by new innovations.

CONCLUSION

We are working at a moment in history when education is changing. For more than one generation into the 21st century, adults have been trying to figure out how to create schools that reflect the changing society and culture. For those generations, adults have spoken of the need to create "21st century schools." (I have a former colleague who would recoil every time she heard that phrase. "It's too late," she would say, "its going be over before we stop talking about building schools for it.") These adults have been grounding all of their recommendations in old and outdated assumptions about teaching and learning and technology. Compounding the problems that arise from this is the rate at which everything changes—what we teach, how we teach, and the tools we have for teaching change far more rapidly than they did for previous generations.

What has become clear to me in the time since I began my career in the field, and even since I started drafting this book, is the schools we need now, and that we will continue to need long after I have retired are will be places where great expertise comes together to create a place that cannot be created by any one individual. Our future schools depend on:

Information technology that is always functioning and available to all students and teachers.

Teaching and learning that is diverse and responsive to the needs to teachers and learners and that prepares all for the unpredictable future.

Decisions made that ensure these schools exist and that all families can send their children to one of these schools.

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