

Efficacious Educational Technology

A Guide for School and Technology Leaders

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Preface

I decided to become a teacher when I was a junior in high school. During my senior year, I had my first experience with computers. I was not impressed. We were introduced to BASIC by our math teacher, but writing the programs seemed far too complicated for me. Looking back, it seems I missed the point as code could be written once, then used indefinitely, and I really did not like doing math on paper. I now know that my high school participated in a very innovative program in which my high school classmates shared computers at Dartmouth College.

I avoided computers until a biology professor in an undergraduate course had us connect to a mainframe computer to draw graphs of our data. With that assignment, I realized computers can be used to draw graphs, which is a very annoying task to do with pencil and paper. Once I realized computers can be useful, I became a computer user, even enrolling in the first “Computers in the Classroom” course offered to undergraduate education students at the university (it was an elective). I continued to be very skeptical of computers and other methods of teaching. I really do not want to waste my time with anything that does not help my students learn and make my life easier. (Notice I did not include “make learning easier for my students.” Learning is hard, and if you find something to make it easy, then you can be sure you are not learning.)

It did not take long before I was regularly using computers in my classes to help my students record data in the science laboratory, create *HyperCard* stacks, explore math, and even create electronic portfolios. I also started serving on technology committees and taking increased responsibility for the computers in classrooms. Now, I work with faculty to figure out the best way to integrate artificial intelligence and use online learning to connect with students who are sometimes on different continents.

Eventually, I was managing the technology in schools, often while also teaching. My positions have included teaching science and math, teaching computer courses, managing desktop computers, training teachers to use

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computers, installing and managing servers and data systems, serving as a technology integration specialist, teaching computer courses to adults in community college through graduate school, serving as an internal and external consultant to administrators, managing learning management systems for community colleges, and conducting research in educational technology.

I have managed the technology others use for their day-to-day work, and I have used the technology that is managed by others. The one thing I have learned is that educators have no business telling technologists what to do and technologists have no business telling educators what to do. But that does not stop either group.

They perform different jobs, follow different approaches, and seek to accomplish different things in their work. It is rare to find individuals highly skilled at both; I can both, but I have typically preferred the education side of my career in “educational technology”—although not always.

Another critical lesson I learned in my career is that if we are going to accomplish anything with technology (any technology, not just computers), then we must be very careful about who makes decisions, how they make decisions, and with whom they collaborate when making the decisions. When decision-making about technology goes badly, we waste time and money, expose data, fail at our duties to protect privacy, and allow poorly integrated systems to distract students and teachers from their work.

In schools (and in other organizations), leaders often seek “collaborative leadership,” and they convene committees that are tasked with recommending changes. I believe collaborative processes result in interventions that provide more benefits in an organization than decision-making by individuals working in isolation. One of the unfortunate realities of such collaborative processes is that committees recommend decisions that make others (often senior leaders who were not involved in the collaborative decision-making process) uncomfortable. When this happens, the committees are often told to “stay in your lane.” I am convinced this happens when the committee was not properly

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charged; it was not told what the boundaries of its decisions were. This means “stay in your lane” is a sign of inattentive leaders.

Despite my attitude towards “stay in your lane,” we do need educators, school IT professionals, and school administrators who do their jobs well and recognize their lanes. The fundamental assumption of this book is that technology decision-making depends on collaborative groups comprising individuals who recognize their lanes, but who also ensure others clearly understand how their decisions affect others.

Audience for the Book

This book was written for those who want to ensure that information technology is an effective tool for teachers and students to accomplish their goals and to ensure it supports the efficient operations of schools. This group includes those who already work in IT and want to begin working in schools, those who seek to enter either the field of education or technology, and those who are already working in educational technology, but who want to improve their performance.

IT Professionals Who Want to Switch Industries

There are many reasons why one might want to transition from business or industry into education. Many are motivated by the desire to support the work of educating; others are motivated by the different working conditions in schools compared to business or industry. Many perceive education as a less stressful industry for IT professionals than other industries. After all, schools continue mission-critical tasks when “the network is down” or even when electricity is out, at least for brief periods. However, many do not appreciate the stress of trying to get a projector to work when a group of first and second graders are waiting for a movie to start.

Some individuals make the switch and begin working in schools, only to discover they are not suited for the environment. When I was an undergraduate studying to be a teacher, the university had updated its program and started to provide field experiences to education majors early in their studies. In previous years, several teacher candidates entered schools in their last semester before graduating only to realize they disliked schools. If you are thinking of switching into education, I hope to help you understand how schools differ from other industries.

Educators Who Want to Switch Their Role in Schools

Some jobs in schools can be very stressful, and while educators may enjoy the environment, they often wish to fill a different role. When drafting this book, I found that several students in my computer information systems courses were educators seeking to transition to educational technology roles. These were students in both community college and workforce development courses. I hope to help these individuals see their work environment from a different perspective.

Those Who Seek Entry-Level Jobs

Schools often hire candidates with minimal experience for entry-level roles. Those who have recently completed associate's or bachelor's degrees or certificates in technology often find schools to be excellent places to begin their careers in technology. In schools, technology professionals develop excellent troubleshooting skills and customer service skills because of the diverse groups of users who interact with their systems. In addition, schools are settings where individuals can expand their IT experience, so technicians may begin to develop network management skills.

Schools are also places where those who are looking to reenter the workforce can find employment. Obviously, this is a generalization, and sometimes hiring committees consist of members who do not understand why people have breaks in their employment. I once had to explain to a school administrator (who was nearing retirement) that switching jobs frequently is not unusual for those who work in higher education and who have worked in grant-funded positions. That administrator perceived a candidate's breaks in employment as evidence that they "could not keep a job." Fortunately, individuals with that perception are rare; most individuals on hiring committees for school positions are not biased against those with breaks in their employment history.

Those Who Want to Improve Performance

IT professionals working in schools are usually aware of complaints regarding the decisions they make and the actions they take. Many of these complaints are based in reality as perceived by individual complainers. These complaints are often denied or dismissed by IT professionals because they are coming from those who “do not understand.” In my experience, these situations are not as valid as the complainers think, but they contain more truth than the IT professionals believe. Through the framework described in this book, these groups will have a common language to better understand the other.

It is difficult to hear criticisms directed toward you and your work. In almost every case, criticism arises out of misunderstandings of what needs to be accomplished. Educators and IT professionals have different lanes; they solve different problems and use different approaches.

I also encourage school IT professionals to introduce this book to the administrators in their schools. They need to be aware of what IT professionals do—knowledge they often do not possess. This book is written with the goal of helping IT professionals understand how they can improve the perceived performance of their departments and to help everyone understand the realities of managing technology in educational settings. With this, both IT professionals and educators will see IT systems from a different perspective.

School Administrators

It is often confusing to hear school leaders speak of the vital importance of IT in teaching and learning yet fail to take an active role in leading how that technology is implemented. Too often, school administrators defer to the IT professional when it comes to technology decisions. The leadership team in most schools consists of individuals with similar professional backgrounds. While they bring various specialties, almost all have baseline training in areas like school law. They share a language and an understanding of the rationale

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for most decisions, but they rarely understand the language and rationale for enterprise networks. Administrators need to be aware of the operational realities that both they and their IT staff often overlook. Within the framework of efficacious educational technology, this book ensures all participants, from the server room to the principal's office, understand their unique roles in a successful digital environment.

Overview of the Book

This book describes Efficacious Educational Technology, my framework for comprehensive and collaborative decision-making in schools. It is organized into these chapters:

Introduction: A Framework and Problem Solving—This chapter introduces the efficacious technology management framework to align school infrastructure with technology-rich teaching. The framework comprises three dimensions: Appropriate Design, Proper Configuration, and Reasonable Implementation. Further, the chapter differentiates tame and wicked problems and describes how each affects different aspects of educational technology.

Part 1 focuses on Appropriate Design and includes two chapters:

Concepts of School: The Origins of Appropriate Design—This chapter contrasts the traditional "standard model" of education—characterized by teacher-centric lectures, passive learning, and rote testing—with alternative, context-rich instructional approaches. It outlines six distinct learning types and argues that school IT professionals must understand these diverse, collaborative, and social methodologies to effectively support non-standard classroom technology needs.

Local Curriculum and Instruction: How Appropriate Design is Communicated—This chapter outlines how local curriculum maps, assessment plans, and standards shape classroom technology needs. It explores four methods of instructional technology—teaching by, about, via, and with tools—and underscores the role of technology integration specialists in aligning IT infrastructure with professional development, digital arts, and collaborative design.

Part 2 focuses on Proper Configuration and includes four chapters:

School Users of IT: Bridging Appropriate Design and Proper Configuration—This chapter describes how school IT users—primarily students and teachers—differ significantly from business users due to emerging skills, dynamic learning needs, and periodic population turns. IT professionals

must navigate distinct roles, support flexible environments, and enforce key federal laws (FERPA, COPPA, CIPA) to safeguard student privacy and maintain digital safety.

End-User Devices: IT People Touch—This chapter explores end-user devices in schools, detailing full operating systems, tablets, and Chromebooks tailored to varied educational needs. Beyond standard computing devices, classrooms utilize specialized tools like interactive displays and makerspace hardware. Effective IT deployment requires balancing computing capacity, diverse application demands, and long-term Total Cost of Ownership (TCO).

Network Configuration: IT Users Don't Touch—This chapter details the hidden infrastructure of school local-area networks, covering network classes, bandwidth, and routing mechanisms. It emphasizes network management, physical and digital security, identity control, and disaster recovery—underlining that robust LAN planning is crucial for reliable cloud access, FERPA compliance, and instructional continuity.

Cloud Computing: IT No One Touches—This chapter outlines how schools leverage cloud computing (SaaS, PaaS, IaaS) to offload server management and scale economics. Under a shared responsibility model, schools focus on identity, access, and data security while utilizing cloud platforms for productivity, LMSs, SISs, library databases, business operations, VOIP, and generative AI.

Part 3 focuses on Reasonable Implementation and includes three chapters:

Relevant Educational Technology Theories: Rules We Should Follow—Grounding educational technology decisions in established theories—such as UTAUT, Cognitive Load Theory, SCOT, and Diffusion of Innovations—ensures effective implementation and clear rationale. Frameworks like TPACK and SAMR further guide leaders in balancing technological capacity with pedagogical integration, minimizing extraneous cognitive friction while fostering meaningful learning experiences. In this chapter, these theories and frameworks are described.

Procedures to Support Reasonable Implementation: Rules We Decide to Follow—This chapter focuses on essential procedures for managing school IT, including efficient device repair strategies like imaging and freezing, along with ticketing and warm-closure support. It emphasizes triaging requests, providing strong customer service, scheduling shared resources, ensuring network security, and executing a continuous improvement design cycle.

Laws, Regulations, Policies, and Budgets: Rules We Must Follow—This chapter outlines the mandatory rules governing school IT, explaining how broad national and state laws, technical regulations, local school board policies, and industry standards shape decisions. Effective IT leadership requires aligning procurement, human resources, and system design with these compliance guardrails to ensure legal safety and data security.

Introduction

A Framework and Problem Solving

Efficacious technology management is a framework for the work of preparing technology-rich teaching and learning and managing the computers and related infrastructure necessary for schools. I introduce the book by defining the dimensions of efficacious technology and the professionals responsible for teaching dimension. I also describe differences in the nature of the problems that educators and IT staff are prepared to solve. These differences arise from fundamental differences in the types of problems solved by educators and information technology professionals.

Schools are and always have been places where information technology (IT) is used by students and teachers. Socrates (the philosopher who was born in Athens, Greece in the middle of the 5th century BCE) did not believe in writing. In Plato's *Phaedrus*, Socrates describes how writing weakens memory and criticizes written words because we cannot ask them for clarification. I suppose it is unlikely he used anything other than his voice and his students' voices for his dialogues. In *Orality and Literacy*, Walter Ong (1982) differentiated cultures with no written language from those with written language in terms of orality and literacy. He also noted the differences in how people are educated in those two cultures and how fundamentally different life is in each. For those of us in literate cultures, information technology is central to our schooling.

Information technologies can be devices where disposable information (chalk writing on slates, markers on whiteboards, displays on calculators, and notes discarded after the test) is kept for short-term needs. Today, we call this type of information volatile, and it is stored in the random access memory (RAM) until we turn our computer off. Some stored information is persistent

like data in our computer's solid-state drive (or stored on Google Drive); that information is intended to be permanent, like books.

In schools, we access information stored in technologies; reading printed text and interpreting images on paper were the dominant information retrieval skills for generations of students. Electronic media presenting recorded audio and video was available just before digital tools came to dominate popular culture, but it was marginal media for teaching and learning in schools where print was available. Much of the information we retrieve today arises from digital sources, and there are far more media available for students and teachers than when we relied on print. Evaluating information is much more difficult, and audio and video are no longer marginalized in the way they were previously as editors have disappeared from many media sources. Today, the modern media is available in more formats than we had before digital tools came to dominate. We see misinformation, parody, propaganda, and other dubious sources that are presented in the same way as credible information is presented (Wineburg et al., 2016; Wineburg et al., 2020).

In schools, we also learn to create information with tools. Pencils (and pens and typewriters) and paper have been replaced with keyboards and mice (and digital drawing pads and haptic controls). Creating information, especially in writing, is a part of how we demonstrate we have learned what we were supposed to have learned; there really is a reason teachers have students write answers to essay questions on tests; it is why we write dissertations to complete doctoral degrees. Generative artificial intelligence tools have been challenging the role of created information as an indicator of what learners know. This is an active area of concern for practitioners and researchers, and we are just beginning to understand how AI might influence education (OECD, 2026; U. S. Department of Education, Office of Educational Technology, 2023).

In the centuries since Socrates, information technology has played multiple roles in schools. First, it is used to present the information contained in the curriculum. By reading, looking at graphs and images, watching videos

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and listening to audio, then writing and otherwise creating summaries, students demonstrate they know the information they were taught. Second, students use the technology tools that they will use when they leave. Technology tools help learners analyze and manipulate information to better understand it, effectively expanding our capacity to use it. Seymour Papert (1980) was well-known for suggesting that technology can serve as a tool for thinking as well. Just as algorithms for performing calculations were technologies taught to math students so they could perform calculations, we have students using calculators and spreadsheets to find answers to calculations today. The pencil and paper and prescribed steps and the spreadsheet are information technologies that we must use to get answers to calculations. Digital tools dominate all aspects of economic, political, and social life in western culture, and schools have a role in ensuring graduates can interact with them.

Digital tools began to arrive in the consumer and education markets with the arrival of personal computers in the late 1970s. In the decades since then, we have seen a steady and rapid expansion of devices available for these markets. The large boxes that held the motherboards and random-access memory and that we booted up only after we inserted the application disk in the drives and the equally large cathode ray tubes that served as displays have been replaced with tiny devices. In the digital world, we have laptops or notebook computers, tablets, or phones that put information and analysis tools in very compact spaces. These devices also connect us to the internet and the effectively infinite information available on its servers.

When I started teaching in the late 1980s, print and writing still dominated. I had a computer at home (purchased about halfway through my undergraduate studies), but not many of my colleagues did. Two years earlier, I enrolled in the “computers in the classroom” course that was available to undergraduate students as an elective in the education department at the time. When I graduated, I needed to demonstrate I could load a video cassette recorder, but not that I could use a computer.

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Interestingly, I had little interest in computers when I graduated from high school. We had them; a small number of them, and they were housed in a book storage room. I now know those computers were part of a program that connected our computers to Dartmouth College. I first used the computers in my senior year advanced algebra course, but I found it far easier to “just do the math on paper” than to write and troubleshoot the BASIC programs we were assigned. Rankin (2018) argued that program was one of several very influential efforts that established computing practices for people. (That program and the lecture I heard Grace Hopper give when I was a freshman in college are things I would experience differently if I could go back in time.)

Once I learned that computers could be useful for tasks like drawing graphs and editing papers, then I became a computer user. In many ways, my career as a computer-using educator has mirrored education’s experience with computers. When I started teaching, computers were no longer in book storage closets, but in computer rooms. I served on the first technology committees at the small schools where I worked. I was a science and math teacher whose students were often found in the computer room. My guess is I was using the computer rooms far more than my share of the time, but no other teachers were using IT—until I started helping them develop lessons.

I have retained my skeptical attitude towards computers and associated technologies that marked my first experiences with computers. If the technology is not useful, then I will reject it. These changes are always open for revision. I was responsible for blocking *Wikipedia* when it first became available, but once I understood it, I unblocked it and encouraged faculty and students to use it. I have similar skepticism regarding any teaching method and most other aspects of school.

The purpose of this book is to describe “good” educational technology. Of course, this is from my perspective. I do claim some expertise in the field, but do not expect readers to believe anything just because it is written here. These are strategies and approaches that appear to have worked (and continue

to work), but they should all be evaluated in specific schools. Use what I have written here against your own goals to decide its value.

Organizational Goals

Goals, objectives, and outcomes are all used to guide what happens in organizations, including schools. Obviously, these terms are all similar, and one who has achieved goals is likely to be doing the same thing as one who has achieved objectives or achieved outcomes. These terms are even more confusing in some schools as they are used interchangeably by some but are clearly defined by others. A former colleague captured all these terms with clarity, when she began any discussion about goals, objectives, or outcomes with the question: “What do we want to be true when we are done?” She was wise, as that question gets to the point of setting goals regardless of the terms used.

Table 1
Types of Organizational Goals.

Goal Type	Focus Area	School Example
Efficacious (Strategic)	Broad vision of the graduate	Embracing forward-thinking practices and global readiness
Effective (IT Operations)	Systems uptime, support, and tech integration	Minimizing system downtime and resolving support tickets quickly
Efficient (User Experience)	Accomplishing more work in less time	Implementing Single Sign-On (SSO) platforms to eliminate login delays

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Schools are complex social organizations, so goals may be differently realized by different groups or different individuals. As a result, deciding whether goals are met or not can be contentious in schools and there is not always consensus among all interested parties. School and IT leaders do have a responsibility to define, track progress towards, and report on progress regarding three types of goals.

Goals to Be Efficacious

Efficacious goals are those that define the vision of the school. In many cases they are called strategic goals. These goals are typically contained in a vision statement defined by the school leaders and approved by the school board or other governing authority. These goals might contain only a few sentences and perhaps a bulleted list, and they describe the characteristics of one who completes the program of study.

These goals are generally not useful for educators, IT professionals, or anyone else to use to guide activities or decisions. While they may not be useful, all who work in schools must be committed to these goals, and in many cases, our job performance is measured by the alignment we draw between these goals and actions we have taken. You should be prepared to define specific departmental or individual goals in terms of these goals.

Examples of goals to be efficacious might include:

- Encourage curiosity, critical thinking, and a love for learning that extends beyond the classroom and throughout students' lives.
- Create a learning environment where every student feels valued, respected, and supported, regardless of background or ability.
- Cultivate student agency by providing opportunities for leadership, decision-making, and meaningful participation in school life.
- Embrace forward-thinking practices and digital tools to enhance teaching, learning, and global readiness.

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- Strengthen connections with families, local organizations, and global networks to enrich educational experiences and foster civic responsibility.

While many professionals, including IT staff, may find such goals difficult to affect directly, we should find meaning in them and they should motivate adults who work in the school.

Goals to be Effective

Within IT departments, goals are defined that are used to determine the degree to which its members have been successful in supporting others' use of technology; we call these goals to be effective. Whereas goals to be efficacious are difficult to use to direct one's work, goals to be effective can be used to direct activities. When one arrives at school, these should tell us what types of projects will fill our day.

Examples of goals for effective IT departments may include:

- Ensure that the school's network, hardware, and software systems are consistently operational, secure, and up to date to support teaching, learning, and administration.
- Provide timely and effective support to staff and students, minimizing downtime and resolving issues quickly to maintain productivity.
- Collaborate with educators to integrate technology into pedagogy, enabling innovative instructional practices and enhancing student engagement.
- Offer ongoing training for staff to build digital literacy and confidence in using educational technologies effectively.
- Align IT initiatives with the school's strategic goals, manage resources efficiently, and plan for future technology needs and upgrades.

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It is easier for professionals to see how they are affecting goals to be effective; however, there is not always consensus that the steps are having the same effects. For example, many teachers want to have administrative access to their computers so they can install software. IT professionals understand this is not a good idea (it is almost as bad as allowing IT folks to teach), as it is likely to introduce new and unintended problems. Teachers with administrative access lead to changes in configurations that both make it more difficult to operate the computer and that leads to the technicians spending an inordinate amount of time trying to fix problems introduced when the teacher installed that fantastic software which they decided they did not need after seeing it.

Goals to Be Efficient

Efficiency describes the ability to accomplish more work in a given time. In general, computers that are deemed easy to use by end users are associated with increased efficiency, so IT departments in schools are charged with both improving the efficiency for users and improving their own efficiency. In my experience, there can be a mismatch between goals for efficiency for users and for the IT department. Consider a login process that takes 15 seconds per user and a resolution to the problem that would take 6 hours of IT work to resolve it. In this case, the IT professionals can easily reason they do not have the time to deploy it. To increase their efficiency, they would leave “fixing the login procedure” off their to-do list. I reason that this is a mistake. When instructors are faced with time constraints and must deal with easily distracted students, the 15-second delay can be a barrier to their efficiency. Goals to improve efficiency are likely to define projects that IT professionals implement. In general, IT departments like to point to improvements in efficiency as evidence their systems are being well-used.

Examples of goals to improve efficiency of schools using computers include:

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- Implement single sign-on (SSO) platforms to minimize delays and improve classroom readiness.
- Automate system updates and monitor network health to prevent downtime during instructional hours.
- Choose educational platforms with streamlined dashboards and minimal setup requirements.
- Use ticketing systems with AI-based triage to prioritize and resolve issues quickly.
- Integrate learning management systems (LMS) with student information systems (SIS) to sync data automatically.

When there is alignment between the three types of goals, then both leaders and members of an organization understand that achieving goals to improve efficiency and effectiveness also lead to the school achieving strategic goals which define efficacious schools.

Frameworks

Defining goals is only one part of leadership. To achieve goals, they must be translated to actions which are often defined in the practices or procedures followed by the teachers and students, administrators, staff, and all other associated with a school. To avoid micromanaging, many leaders adopt frameworks which are based in established research findings. When leaders choose frameworks aligned with the practices they want to encourage, then the practices and procedures should align as well.

School leaders today seek to be “evidence-driven.” They (quite reasonably) want to be assured that what they are doing will have the intended effects—that their strategic goals to be efficacious will be met. Research is an endeavor intended to define things that are true, so leaders use it to support decisions. In reality, it is difficult to base decisions on research. When looking at research, there is that which has been established and there are emerging

findings which are less reliable. All new research discoveries are tentative, and in many cases, the newsworthy stories that are widely discussed are not replicated, so they are discarded. Even with replicated findings, it may take several years before they are fully integrated into theory. Further, research is often conducted in highly controlled settings, and schools are not highly controlled. For those reasons, it can be difficult to use research findings to guide actions in schools.

While research may not be useful for planning goals and preparing interventions, frameworks are. A framework is a conceptual description of how a certain aspect of the world works. It is based in theory but tends to introduce its part of the work in a brief paragraph or two and it is defined by dimensions (which are largely independent) that describe how it works in further detail. In this book, I present efficacious educational technology as a framework in the next section (just a couple of pages) that takes the rest of the book to detail how it can be implemented. This is typical of those who describe frameworks.

Frameworks do not prescribe specific actions but offer a lens through which educators and IT professionals can design, evaluate, or reflect on their work. One of the benefits of using frameworks to guide goal setting and intervention planning is they establish a common language which facilitates focused planning and helps decide whether goals have been achieved. Brad Mehlenbacher (2010), a scholar at North Carolina State University observed dimensions that are accurate, relatively non-complex, suitably generic, and modifiable are most suitable for defining frameworks that facilitate communication within organizations and between practitioners and scholars.

Accurate

Frameworks are grounded in established research. The term grounded means it is guided by established theory, and its authors refer to it and base their claims about the framework in the way the theory suggests. This aspect of frameworks does allow practitioners to be able to make predictions about anticipated changes and to explain the changes due to the theories detailed in

the research. It also allows practitioners to use valid and reliable instruments when gathering data.

In political organizations, which include schools, many decisions and practices are grounded in discussions which may be made without any intention of being accurate. Remember, most aspects of school are places where wicked problems arise, so the “facts” that support claims of accuracy can be differently interpreted. For example, there is ample research that starting school days later in the morning benefits adolescent learners (Minges & Redeker, 2016). Despite this, there are many schools that have not changed the start time for schools, and in many cases the decisions are grounded in differing interpretations of the research. In many cases, interested parties conflate their opinions with research, so it is important that the research grounding frameworks be made explicit.

Relatively Non-complex

Educational researchers go to great lengths to explain the conditions under which they collected their data. These details are important to other researchers who must assess the transferability of the research, and others may want to replicate the findings. This detail results in much research being too complicated to guide decisions on schools. As a result, when defining frameworks, we use language that is less complex than we find in research.

Suitably Generic

The complexity of research findings results from the details of the study participants and the conditions that produced the findings. In schools, we deal with the students who are actually present and teach the curriculum that is specified. This specificity limits the application of research findings to many settings. The established research must be selected and communicated to users of the framework in such a manner that it is appropriate for all settings in which it will be used.

Modifiable

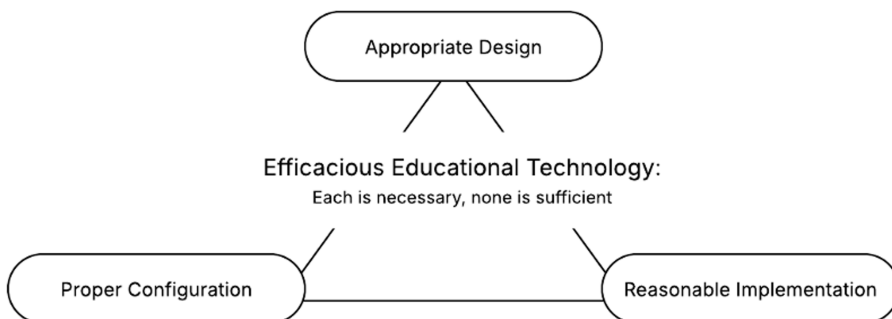
One of the defining characteristics of scientific theory is that it changes, but it changes only when new observations or more satisfactory theory become established. An educational framework and its dimensions define the characteristics of the domain that are supported by current knowledge and within that there will be various practices that are justifiable. Educators may select from those practices based on political or personal preferences, but the dimensions of the framework can only be changed based on empirical and logical evidence.

Defining Efficacious Educational Technology

Efficacious educational technology is a framework I defined in my 2018 book. The current book is a revised edition of that one. The purpose of this framework is to describe a strategy for ensuring that technology is used to reach goals set by leaders and those who govern schools. It comprises three dimensions. It should be noted the three dimensions are all necessary for efficacious educational technology. If we accomplish two of these with perfection, but ignore the third, then we cannot succeed. The dimensions are appropriate design, proper configuration, and reasonable implementation.

Figure 1

Efficacious Educational Technology



Appropriate Design

When I was an undergraduate studying to be an educator, my classmates and I took great care in lesson planning; we thought carefully about what we wanted to teach and how we were going to do it. As I started teaching, I discovered the plans are fine, but classrooms are spaces where plans run up against reality, so they must be designed to respond to that reality.

Educators begin with plans, but they update those plans depending on the realities of the students and their interactions with the activities that comprise the lesson. These updates are called designs. Students' previous experience, their cultural backgrounds, the social interactions in classrooms, and their interests are among the complex and unpredictable factors that affect educators' designs. Designs also react to changes in the curriculum. For example, a new math curriculum may change designs from year to year. Even what happens in the hallway just before class starts can affect the design of a particular classroom. We also realize goals were misguided in our initial plans or we come to deeper or different understanding of our plans; all these factors affect the appropriate design of classrooms.

Decisions about what represents appropriate design are made by teachers and other curriculum leaders. They understand the students the best; they understand the curriculum, instruction, and assessment far better than any IT professional; thus they should be making decisions about how technology will be used in the classroom. I am an educator; much of my career has been in the classroom. I am a scholar of education. Still, I rarely question teachers about their decisions about appropriate design.

Classroom design includes both physical places and online spaces. The IT department may have something to say about how to properly configure hardware, software, interfaces, and other aspects of the design, but decisions about how IT will affect teachers and learners must be made by educators. If there is alignment between what happens in classrooms with technology and the strategic goals of the school, then appropriate design is an essential aspect of efficacious educational technology.

Proper Configuration

The second dimension of efficacious school technology is proper configuration. It is through the work of a team of skilled IT professionals that computers and networks meet the needs designed by educators for students (and staff for operational purposes) and remain functional.

It is the job of IT professionals to ensure the IT systems in schools are secure, reliable, and robust. Computers must be properly configured and managed if they are going to be useful for students and teachers. To do this, they fix broken devices, perform preventive maintenance, and manage firewalls and other security devices. This is the most familiar to IT professionals as it requires similar steps to proper configuration regardless of the organization. If you set up organizational units in Windows when working for a business, then you know how to organize them in schools.

Reasonable Implementation

The third dimension of efficacious school technology is reasonable implementation. This is defined by decisions that school leaders make. Educators and IT professionals want lots of technology. However, school leaders to keep within budgets, make decisions to keep within budgets, ensure relevant laws and regulations are addressed, and enforce school policies—all of which define reasonable implementation.

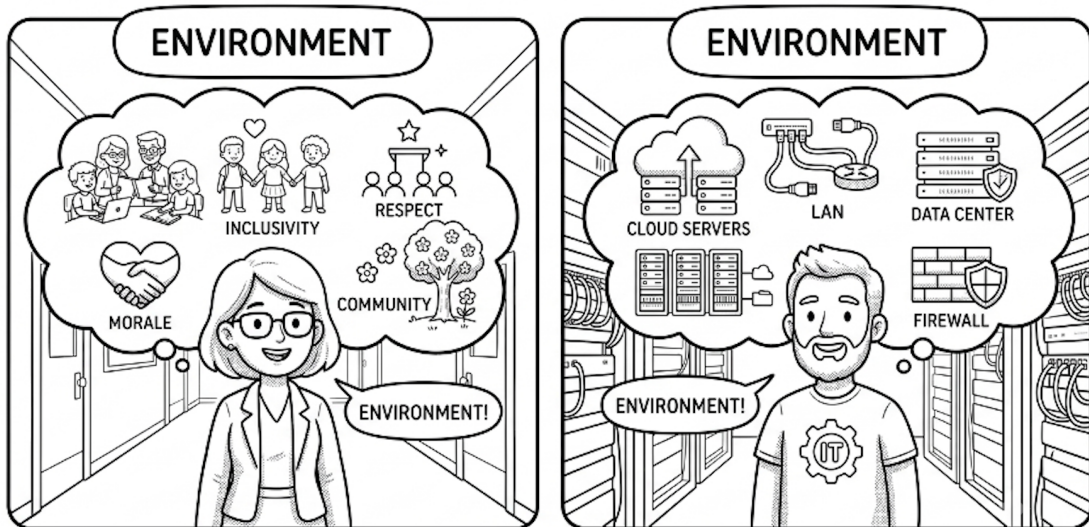
On Collaboration

It is very unlikely that a single individual has the skill to make sound decisions about more than one of these dimensions. As a result, schools in which there is efficacious educational technology will have a steering committee or other strategies in use to ensure educators affect decisions about design, IT professionals make decisions about configuration, and leaders make decisions about implementation.

The dimensions are independent but connected. Language can be an important element in ensuring interested parties do not affect decisions they should not make. I once served on a committee hiring a professional who was primarily going to serve as network administrator.

We were in the second interview, so there were fewer questions and more discussions, and the applicant asked, “What can you tell me about the environment?” The superintendent (who admitted little knowledge of technology) began describing efforts they had made to improve the working climate in the schools. The candidate looked puzzled as he listened for several minutes. When she paused to take a breath, I interrupted, “I think he was asking about the network environment?” He said, “yes, I’m glad to have heard that, but I was asking about the servers and stuff.” Sometimes IT professionals and educators are not even speaking the same language even when they use the same word.

Figure 2
Different Meanings for the Same Word



ALIGNMENT REQUIRES A SHARED DICTIONARY, NOT JUST SHARED WORDS

Types of Problems

Those who create appropriate designs, proper configurations, or reasonable implementations solve problems. Many are easy to solve; others are more difficult to solve. Some are never solved, and some are solved when people leave. There is a framework for understanding the type of problems we address no matter which aspect of efficacious educational technology is our responsibility.

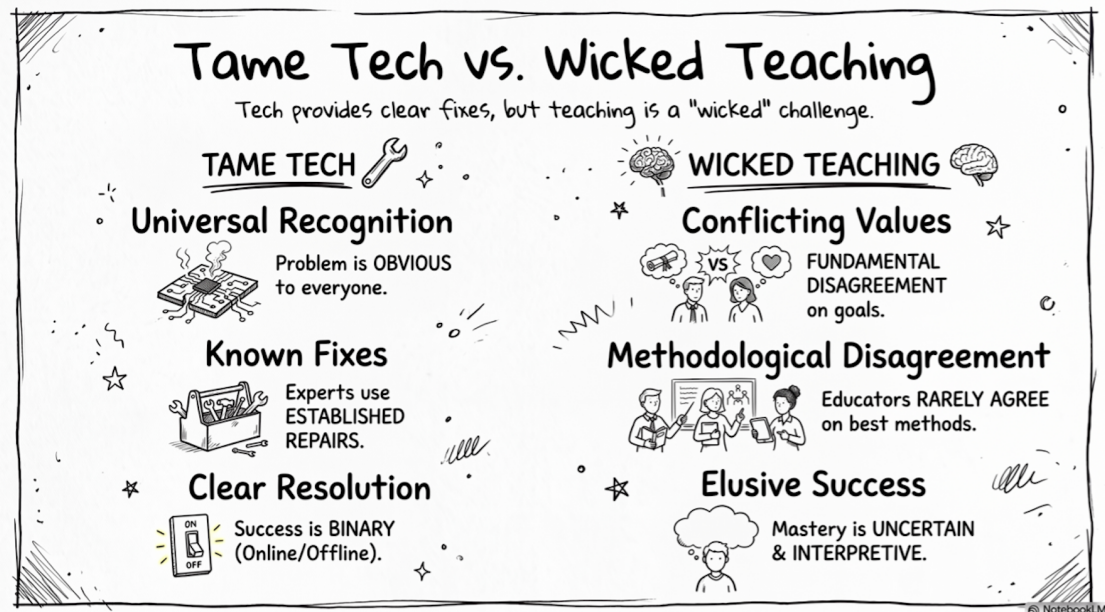
In the 1973 article, “Dilemmas in a General Theory of Planning,” Horst Rittel and Melvin Webber, professors at the University of California, differentiated two types of problems: tame and wicked. While both can be complex and difficult to solve, tame problems are definable, understandable, and consensual; whereas wicked problems are hard to define, difficult to understand, and are not always recognized as problems and solutions are not always agreed to be solutions. Maintaining efficacious school IT comprises both tame and wicked problems and how we approach and solve them matters. It matters a lot. Mishra and Koehler (2006), who are well-known for Technological Pedagogy Content (TPACK), which is described in the chapter entitled Theory and Educational Technology, describe teaching as an ill-structured problem requiring complex thinking, and they refer to teaching with technology as an explicitly wicked problem.

Tame Problems

According to Rittel and Webber, tame problems have three characteristics:

- *Definable*—We understand what the problem is.
- *Understandable*—We know its cause and its effects.
- *Consensual*—We all agree it is a problem and will recognize when it is solved.

Figure 3
Tame Versus Wicked Problems



I typically explain tame problems with the example of someone who is having a stroke; this is because I had one in my early years of knowing the definitions. My stroke was a blood clot in my brain, and the emergency medical technicians, nurses, and doctors all knew what was causing the symptoms, and the potential effects. They also had a pretty good idea that if they cleaned it out, I might survive. Everyone also agreed it was a problem that needed to be solved, and if they did not, then I was going to die.

Tame problems are solvable by recognized strategies. Once we know the cause, we know how to solve it. In the case of a stroke, they know the drugs to administer, the tools to insert into the brain, and the knowledge of how to administer them and how to insert them to remove clots (at least in those of us lucky enough to have had access to treatment). These were all tested in medical studies and on previous patients treated by the team who treated me.

Horst and Webber used the term tame to capture the definable, understandable, and consensual nature of these problems. Tame did not mean

the problems were simple to solve or that the problems were not important and ethically challenging. Tame did mean that the problems were generally studied and solved through science and engineering that was guided by defining goals and thinking about systems. While recognizing that no problem can be completely tame, Rittel and Webber suggested that the living conditions for large populations of humans had been improved by solving tame problems related to (for example) health care and medical procedures, transportation and sanitation systems in cities, and agriculture.

In school IT, we solve tame problems with less drama than in emergency rooms, but when the “network is down,” technicians and system administrators identify it. They often know the problem. (Ask an IT person sometime “what is most likely to bring your network down?” and they can tell you. Well, actually they probably won’t as it may be something that could be a security breach if it was revealed.) Once they are sure they know the problem, they know how to fix it, or they know how to get assistance fixing it. The system can then be tested before it returns to service, so they know their solution worked.

Wicked Problems

Rittel and Webber contrasted tame problems with those they called wicked. These problems cannot be easily understood, are not completely definable, and there is no agreement about the existence and resolution of the problem. In many cases, wicked problems include a human or social element, and this contributes to their nature as:

- *Ill-defined*—It is hard to know the cause of a wicked problem, and when we do define a cause, we often find we were wrong, or we have identified a minor cause so that when we resolve that one cause, the problem will remain.
- *Hard to understand*—Because causes are ill-defined, we find it difficult to know the effects of those causes. When we can clearly define cause and effects, we are said to understand the phenomenon. When we are

faced with wicked problems, causes, effects, and our understanding changes when we look at it from different perspectives.

- *Not consensual*—Wicked problems are almost always social problems, and when we define them, they are always defined from one perspective. It is completely accurate to say that a single solution can be both a “win” for one group and a “loss” for another. One key indicator that you have been working on a wicked problem is that different people will have logical and accurate reasons why the solution has not benefited them or (more likely) made it (or another problem) worse.

When defining the strategic goals that they agree will define efficacy, school leaders create a wicked problem for themselves. We know schools are designed to “make students smart,” but what exactly does that mean, how do we measure it, and how do we accomplish it? Those are among the most challenging wicked problems we address in schools. My career in education started decades ago. Long enough that I have seen the trends of “cutting edge” and “innovative” teaching practices come and go and come around again. The reality is that if teaching was a tame problem, we would have solved it by now.

How We Solve Problems

Understanding the differences between tame and wicked problems is one of the fundamental aspects of managing school technology in an efficacious manner. When we are faced with a tame problem but address it as if it were a wicked problem, frustration follows. Those who know the problem want to solve it; but those who are more familiar with solving wicked problems are searching for a deeper problem. Conversely, when we face a wicked problem, but we try to solve it as a tame problem, we also see frustration. Those who see its wicked nature want to come to a deeper understanding, but those used to tame problems, define the problem and solve it, often solving it only for themselves or those with similar perceptions of it.

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This is one reason we maintain independence when planning for efficacious educational technology. Educators make decisions about the wicked problems we encounter in design; IT professionals make decisions about the tame problems of configuration. School leaders solve whatever problems arise, sometimes making the wicked decisions to let the IT professionals do what needs to be done.

Part 1: Appropriate Design

Having started my career as a teacher, it is fitting to begin this book by examining educational technology through the educator's lens—exploring how teachers conceptualize appropriate design. While I do not hide my pedagogical preferences in these chapters, the core principle remains: the technical preferences of IT professionals should not dictate educators' instructional decisions.

In the first chapter in Part 1, *Concepts of School: The Origins of Appropriate Design*, I examine common assumptions about schooling, explain why traditional models can be limiting, and introduce alternative teaching methodologies that—while unfamiliar to some—are strongly supported by the learning sciences. In the second chapter, *Local Curriculum and Instruction: How Appropriate Design is Communicated*, I turn to local educational practices, demonstrating how curriculum maps, assessment plans, and instructional standards translate pedagogical goals into specific technology needs.

Concepts of Schools

The Origins of Appropriate Design

Schools are familiar places to most adults. We have experience in many different types, when we were different ages, and many of us have observed children who are important to us during their career as students as well. It would seem these experiences of schooling prepare adults to work as information technology professionals, or any other role, in schools, but the reality is schools are many more things than most people's experience allows. In this chapter, we explore what school can be, including many concepts of schools contrary to what you imagine.

Imagine a classroom. Look at the physical arrangement of the space. Look at the people and imagine what they are doing. It is very likely you imagined many more students than teachers (or other adults). The adults were standing, while the students were sitting in rows of desks that were arranged in rows; in recent years, the desks may have been replaced with tables. If you imagined someone talking, it was probably an adult, and if a student was talking, they were probably answering a question that was posed by an adult.

Look at the materials being studied. There were probably books or pieces of paper on students' desks, a chalkboard or a whiteboard (or today a large computer display) at the front of the room where students' attention was supposed to be directed. In many classrooms there would also be maps, charts, posters, and other paper on the walls to communicate the curriculum and motivate students, as well as to give them emergency procedures.

If you imagined a classroom setting in which the teacher was trying to find out what the students had learned, it is very likely you pictured the students taking a test—answering questions on paper, with no other resources other than what is in their brains. Later, teachers will check to see which answers had the correct answers. Those who got the most questions marked

“correct” will be judged to have learned more than those who had fewer marked “correct” are judged to have learned less.

This is the type of classroom I attended as a youngster and sometimes as an adult (as a graduate student, classroom settings were often different). It is the classroom that sometimes characterized the classrooms in which I taught (as I learned more about learning my classroom changed), and it is the type of classroom in which my children were students. It is very common in popular media.

In this chapter, I challenge the standard model of education so common in media, including the ideas that teachers always deliver instruction and students’ scores on tests are associated with their ability to use that knowledge in other settings. I describe the variety of activities we classify as learning, and I describe alternatives to the standard model that I expect you imagined and that have been used to teach generations of students.

My goal in writing this chapter is to broaden your understanding of what constitutes appropriate education. This chapter describes some of the reasons educators may approach you as an IT professional with some crazy ideas about what to do with computers. The craziness arises from the fact they may have a very different concept of what their students need than you do, but it is your job to make it reality. I will be successful if you understand the many and changing factors that determine what educators want to do with the computers you manage.

Your Experience

I assume most readers of this book have spent a part of their lives as students. It is likely you were a student in elementary and secondary school. You may have experience with post-secondary, for example a trade school, community college, or a four-year college or university. Your experience as a student may be in workforce development courses, or you may have been in conferences of professional development activities.

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All these experiences affect how you approach the work of being an IT professional in a school; they will bias your beliefs about the school. We assume everyone's experience in school was like ours. We also assume we have an accurate memory of our own schools. We assume that everyone should learn what we learned and how we learned it. As a result, many adults pursue work in schools with the intent of replicating the structures and instruction they experienced, but that may not be what all students need.

The reality is that even for your classmates, the experience of school was very different. We know as well that human memories are very unreliable, so what you think you experienced in schools is not accurate. Further, there are many types of activities that lead to what we call learning. Some of what you learned happened because of what teachers did, some you learned despite what they did; and in some cases, what they did made it more difficult to learn what they intended to teach.

As we become skeptical of our experiences and popular culture's concept of school, we will become more open to alternative ways of designing classrooms. According to the dimensions of efficacious educational technology, IT professionals are not responsible for making decisions about appropriate design. If we understand the ideas that affect different views of education and teaching, we will be more aware of the potential bias we have against certain designs. We can better understand the rationale for educators' designs, even those that make us question "what we know."

Adults who want to work in schools tend to fall into one of two groups. There are those who liked school or were successful in school; individuals in this group tend to advocate schools that reflect their experience. There are those who did not like or succeed in school; those individuals tend to advocate different organizations and different types of teaching than they experienced. While this is an oversimplification of the nature of these groups and the composition of educators, it is noteworthy that both groups include individuals who value school enough that they want to work there and support today's

students. The perceptions, experiences, and biases of individuals who never return to school in any capacity are silent in the design of schools.

Not only are school IT professionals confused by the requests made by some educators, but educators are sometimes confused by the requests made by other educators. When I was in school, I described myself as one who could “get a C in math.” For some reason, despite being a very skilled thinker about mathematics, I struggled with the methods of teaching math used by my teachers. Despite this background, I became a math teacher. I was generally well-liked by my students (especially those who struggled with math). I was not as popular with the other math teachers, however, as many of my approaches were contrary to what they expected.

One of the most important things to remember as you consider a position working in a school is that your education deserves no special consideration. While IT professionals may not exert direct control over teaching and school management decisions, the priorities they set and the devices and configurations they deploy do exert influence on what happens in classrooms and how it happens. When working in schools, IT professionals are often asked to build systems that do not make sense to them as it is contrary to their expectations. It is the IT professional’s role to ensure whatever technology that educators need functions as it is expected. In general, IT professionals should avoid telling teachers what technology they should install or how to best use it in their classrooms. In the same way, educators should avoid telling IT professionals how to configure technology.

The Standard Model of Education

I introduced the chapter by describing a very common concept in school. I expect most readers had a similar concept in mind, and we see the that type of schooling portrayed in the popular media. It is such a popular concept, that I call it the standard model of education (Ackerman, 2017). It comprises several assumptions about teaching and learning:

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- **Telling is teaching**—Most teaching in the standard model of education comprises teachers lecturing or otherwise communicating to students in a direct manner the information they are supposed to learn. While this seems to make sense as they are experts in the field, thus they know more than the students (or their parents) most of the curriculum being taught. However, it generally assumes the students are passive recipients of knowledge. When students are passively interacting with the curriculum, they do not learn as much as when they are interacting with the curriculum.
- **The curriculum is reliably known**— The curriculum is supposed to prepare students for this life, but we really do not know what will be needed. It is largely drawn from the experience of the adults (in schools and outside of school) who write the curriculum; it is reasoned that the information and skills those adults needed represents the information and skills students will need. Schools are also largely isolated from the space where the information and skills will be used. (John Dewey, the influential American educational philosopher, disputed this. A famous quote from Dewey is “Education is not preparation for life; education is life itself.” It has been used by many educators, and it comes from his 1916 book *Democracy and Education*.) Regardless of Dewey’s ideas, we do expect students to learn in school what will be necessary to fully participate in the economic, political, and cultural life of society.
- **Teachers can reliably teach the curriculum**—Teachers are responsible for instruction which are the activities intended to ensure students will learn the curriculum. Despite the many instructional strategies taught to teachers, the methods do not always work. That instruction that does work typically improves students’ ability to recall information to answer similar questions or solve similar problems. When students are faced with unfamiliar problems, they are less successful.
- **Tests accurately measure learning**—Tests call for students to provide answers questions provided by the teacher (or some other author); the

number of those answers deemed correct this is a measure of how much the student learned. There is much potential for error in testing and there is little correlation between performance on the test and the ability to use the information in other settings; this is largely ignored in those courses where testing is the dominant method of evaluating students' learning.

Sawyer (2006), a scholar who focuses on creativity, concluded that the practices I call the standard model of education, are largely based on false assumptions. The reality is classrooms activities in which students are active participants in the work improves learning; this has also been demonstrated by in the ICAP framework (Chi & Wylie, 2014) which suggests, interactive learning is better than constructive, which is better than active, which is better than passive. While there are lessons that are developmentally appropriate for learners through their lives, much that is in the curriculum has been invented for convenience and much instruction does not have the anticipated outcomes. There is also evidence that those who can pass tests do not have the ability to do anything more with the knowledge than pass the test (Soderstrom & Bjork, 2015).

For IT professionals, the standard model of education comprises classrooms in which the technology is easy to configure and manage. When teachers are instructing, some simple hardware and basic software is adequate for what is happening. We provide a teaching station connected to the Internet, some applications including a web browser, a projector, and a screen that can be seen by the entire class, and a productivity suite (most likely Google Workspace in schools) and the essential technology is in place for the standard model of education. With the increasing availability of one-to-one classrooms, we are also likely to provide a single computer to each student. Perhaps the most difficult part of that IT configuration is ensuring that laptops batteries remain charged throughout the lesson.

Eric Mazur, a physics professor at Harvard University, observed in the late 1990s that many physics graduates from Harvard were unable to answer problems in which they needed to apply lessons from the courses they had just completed. He found that adapting lessons to focus less on lecturing and more on student interaction, through an approach he called “peer instruction” (Mazur, 1997) improved students’ abilities to apply what they learned in the physics curriculum.

In many schools, there are teachers (maybe just a few, maybe many more) who use methods other than the standard model. For IT professionals, this matters because those educators will likely require more flexibility than what is necessary for instruction-based teaching.

IT works in a world in which quality matters, but quality is in the eye of the beholder. It is our job to ensure systems are secure, robust, and reliable, but if our users do not perceive IT as able to do what they need it to do, then they perceive it to be of poor quality. While we may have technology for the standard model perfectly configured, if that is not what is wanted by the users then we are obligated to update our systems. This idea is a recurring theme in the book, but at this point, it is enough for readers to understand not every classroom IT configuration, even those we think they need, will be judged as good by the teachers in those classrooms.

Types of Learning

Schools are places where learning occurs. This seems an obvious statement, but exactly what one means by “learning” can cause disagreement among educators. We do know learning does cause changes in the brain, but there is evidence that other systems in the body affect learning, and there is a role for the environment, including both technology and other humans, in human learning.

Table 2
Types of learning

Learning Type	Definition & Mechanism	Key Characteristics	Academic Context
Habit Formation and Conditioning	Learning that becomes automatic in specific situations	Happens gradually and without awareness; strengthened by rewards	Inappropriate for academic contexts, but rewards remain common
Observational Learning	Learning by watching and modeling others	Known as "no-trial learning"	Dependent on the social environment; learners take behavioral adults and peers
Implicit Pattern Learning	Unconscious acquisition of regular patterns within a specific environment	Requires extended exposure to recognize regularities	Examples include language acquisition and understanding visual data like science graphs
Perceptual and Motor Learning	Skill acquisition developed through sensory experiences	Requires long hours or decades of practice, permanently alters the senses once developed	Examples include music, arts, sports
Learning of Facts	The acquisition of specific, isolated information using language	Retained long-term through repeated retrieval practice spread over time and connections	Closely associated with the traditional model of schooling
Learning by Making Inferences	Forming possible explanations world, even when incorrect	Centered around mental or physical representations to predict outcomes	Can be challenging due to implicit misconceptions, making guidance necessary

In academic situations, including large amounts of educational research, recall is assumed to be the only measure of learning. For researchers, it is easy to measure, thus it is commonly used; and it is the reason testing is the dominant model of measuring learning in the standard model of education. It seems reasonable that “remembering” is essential for learning, as we can’t use information if we don’t know it.

If we are to do more with what we learn than recall it, it means we must explore more ways to learn rather than the standard “telling” in its various forms in standard model of education. One of the best recent sources of information about human learning is *How People Learn II*, a book published by the National Academies of Sciences, Engineering, and Medicine in 2018. *How People Learn II* is the third edition of a book published in 1999 and expanded in a 2000 edition. The authors describe five different types of learning.

Habit Formation and Conditioning

Habits result from deeply ingrained learning that becomes automatic in specific situations. This type of learning, which includes classical conditioning, happens gradually and often without conscious awareness. Habits are generally strengthened when they are closely followed by a reward. While habits and conditioning are well known in both humans and other species, most educators have discovered that these are not appropriate models of learning for most academic situations. Despite that reality, it is still common for educators to speak of the need to reward students for behaviors including that associated with academic learning.

Observational Learning

Observational learning is the process where people learn by watching and then modeling the behaviors, attitudes, or emotional expressions of others. This is an advanced cognitive skill, sometimes called “no-trial learning,” which allows a learner to quickly add new behaviors to their repertoire while avoiding the potential costs of trial-and-error. Successful learning by observation

requires the individual to pay close attention to the essential parts of the modeled behavior while ignoring irrelevant features and then being able to remember and replicate what they saw. Sometimes learners cannot differentiate between relevant and irrelevant tasks, so they may perform unnecessary tasks. The social environment is highly important in this type of learning, as people readily take cues for how to behave from role models like teachers or parents, and especially from their peers. **Implicit Pattern Learning**

Implicit pattern learning, also known as statistical learning, involves learning regular patterns within a specific environment without actively setting out to do so. This learning is unconscious and requires extended exposure to a pattern so that the learner can recognize regularities even in an irregular context. Language acquisition serves as a great example, as people spontaneously use the embedded regularities of language to produce correct forms, such as forming the past tense of a new verb, without consciously knowing the rules. This type of learning is also common in visual settings. When I was an undergraduate student studying science, my classmates and I could have discussions about what we expected the results of experiments to be by sketching graphs.

Perceptual and Motor Learning

Perceptual and motor learning refers to the way an individual acquires skills primarily through sensory experiences, focusing on the development of skills through practice. Examples include learning to play a musical instrument, improving a sports technique, or learning to discern subtle differences in sensory information, such as distinguishing between specific musical chords. Achieving high levels of skill through this type of learning typically requires many long hours or decades of practice, as there are usually no easy shortcuts to skilled performance. A surprising result of this learning is that the senses themselves are changed by the experience; once you learn how to see, hear, or feel something in a new way, it can be extremely difficult to return to the previous, less-skilled perception.

Learning of Facts

Learning facts is the acquisition of specific information, such as historical dates or scientific terminology. This is an area in which humans particularly excel compared to other animals, and it allows for the efficient communication of critical information using language. While it is possible to remember a striking fact after only a single exposure, most facts are retained and strengthened only through repeated retrieval practice, especially if the practice is spread over time and contexts. Learning is promoted when facts are connected to other knowledge the learner already has, helping to organize isolated items into a richer mental structure that is easier to remember. This is the model of learning we most often associate with the standard model of education.

Learning by Making Inferences

Learning by making inferences involves forming possible explanations to make sense of observations and move forward in understanding the world, even when the conclusions are not guaranteed to be correct. A key form of this learning is model building, where individuals or educators create mental or physical representations (like a diagram of the solar system) to understand complex phenomena. An accurate model provides a significant advantage because it allows the learner to make reliable predictions about entirely new situations that extend well beyond their initial experiences. However, inferential learning can be challenging, as people often rely on implicit models that may contain misconceptions, meaning that receiving guidance during discovery is often necessary for effective learning.

Tacit Knowledge

Philosopher and scientist Michael Polanyi (1966) used the term tacit knowledge to describe understanding that is implicit and difficult to state with precision. For this reason, tacit knowledge cannot be stated as an algorithm, so it cannot be downloaded to digital devices. According to Polanyi, tacit

knowledge is necessary to frame a problem, to develop a strategy for solving it, and to predict and evaluate the outcomes of the solution. Humans alone have the capacity for tacit knowledge, and they develop it through experiences that Polanyi calls indwelling. Through indwelling, explicit knowledge is deconstructed and then reconstructed by the student while modeling the actions of the teacher (and other experts) and by reflecting on the knowledge and its application. It is through well-developed tacit knowledge that humans understand which problems to solve and how to apply the capacity of technology to solve problems and how to interpret ambiguous results.

The realities of indwelling clarify the need to keep the three dimensions of efficacious educational technology connected, but separate. It reinforced the need to allow teachers to teach, technicians to configure IT, and leaders to lead.

Learning is a Social Process

The concept of the “blank slate” has been discredited among philosophers, psychologists, and other scientists for several decades, but many educators continue to assume students arrive in classrooms with no relevant experiences and that students need only to pay sufficient attention to learn the information teachers tell them. Educators with a more sophisticated understanding of learning and learners recognize both social and individual factors affect how and what is learned in their classrooms and they recognize recalling information on a test is not the same as being able to use information in social situations. Scholars are recognizing that the social environment, the nature of the individuals and groups of people with whom we associate are among the chief determinant in how we learn. Rather than focusing solely on innate abilities or general human experiences, research has increasingly adopted a sociocultural view of learning, recognizing that all learners grow and develop in culturally defined ways within culturally defined contexts.

Humans are born in a state of neoteny; compared to other primates, we are born very early so human babies are unable to care for themselves for several years. Our brains continue to develop long after we are born, the result

is that human culture and society play a very important role in human development. Michael Gazzaniga (2008), a noted neuroscientist who has studied human brains for decades, concluded “the shift to becoming highly social is what the human is all about,” (emphasis in the original) and he continues, “our higher intellectual skills arose as an adaptation to our newly evolved social needs” (111-112). It seems that brains and social interaction emerged together; we need our brains to build social connections, and our social connections affect how our brains develop and in adult life as well. Wexler (2006) observed, “even when fully developed, the self-regulatory, self-direction of attention is far from autonomous, and social input remains a built-in feature of these mechanisms throughout the lifespan” (p. 106).

Culture is defined as the learned behavior of a group of people that reflects their traditions and is transmitted socially from generation to generation. Humans seem to follow the logic, “I need people to survive, so I am going to do what they do, say what they say, and value what they value.” These cultural norms are developed very early in childhood, so when children enter school, these are deeply embedded. While humans share fundamental brain structures and developmental stages, the individual's precise experiences shape these phenomena, meaning learning does not happen in the same way for all people. Understanding the cultural, contextual, historical, and developmental factors that affect learning helps educators create optimal learning environments.

Schools, of course, are created to reflect the dominant culture, so these influences continue as children become adolescents. Especially as regions become more culturally diverse, there can be conflict between the learner's culture and the culture of school.

Learning involves a dynamic, complex interaction between the individual and their physical and social environments throughout life. The biology of the brain provides the physiological platform for learning, but it is continuously shaped by social and cultural influences. We know that emotion is deeply connected to learning; if one has positive emotional connection to the

teacher, the environment, and the content, they are more likely to learn. Stress is also connected with learning. Some stress is good for one to learn, but too much stress, often called chronic stress, can adversely affect learning.

Better nutrition, sufficient sleep, and more exercise are all associated with improved learning (Hillman et al., 2008, Sapolsky, 2004). These factors challenge “more time on academics” approach that is often called for to improve learning.

Approaches to Schools

In the previous section, I described learning for individuals. The types of learning along with the diverse social and environmental factors that create the environment all affect how each person learns. Schools, of course, are spaces where we seek to teach large numbers of people. We expose groups of students to similar ideas (the curriculum) and similar activities (the instruction) in hopes they can use that information in their lives.

The approach one takes when planning curriculum and instruction varies depending on the nature of the course and the preferences of the instructor. When I taught computer courses for middle school students, there was always a debate about the nature of the courses I taught. Typically, there were adults (including teachers and parents) who wanted me to teach keyboarding; they reasoned, “all students must know how to interact with computers, so knowing the QWERTY keyboard by touch is a life skill.” That was a reasonable approach to the course, but it was not one I accepted for a number of reasons.

In this section, I describe some of the approaches to education that one is likely to encounter in school today. These are not always explicitly stated, but sometimes they are. It is common, as well, to see groups of educators have active disagreements about which is the appropriate method for the particular subjects, lessons, or activities being taught.

Teachers who reject the standard model of education tend to adopt certain practices compared to their peers who have not rejected it. They include a broader collection of skills and knowledge into the curriculum and “learning how to learn” becomes more important than “learning what you need to learn.” They recognize no single teaching strategy works for all learning goals, so students have diverse experiences in classrooms where teachers have rejected the standard model. Students in these classrooms demonstrate learning in many ways, including authentic performances that are viewed as interesting and relevant outside the classroom (National Research Council, 2012).

Deeper Learning

Deeper learning is a concept that has been around for decades, and it has been named many things over the decades. I track its most recent iteration from a 2002 article by Collen Carmean and Jeremy Haefner. Each variation is accompanied by suggestions for describing the nature of teaching that promotes deeper learning with some nuanced differences, but several common elements. Those elements include:

- Teaching focused on complex problem solving which requires learners to apply what they have learned in unfamiliar situations.
- Students framing complex problems and solving them (or attempting to solve them) rather than only learning about the problems or others’ solutions to them.
- Thinking critically, creatively, and practically about the complex problems and the potential solutions.
- Declarative knowledge presented in a manner that is connected by themes and concepts rather than as isolated facts.
- Students are involved in assessing their own learning and actively identifying and resolving gaps in their knowledge.

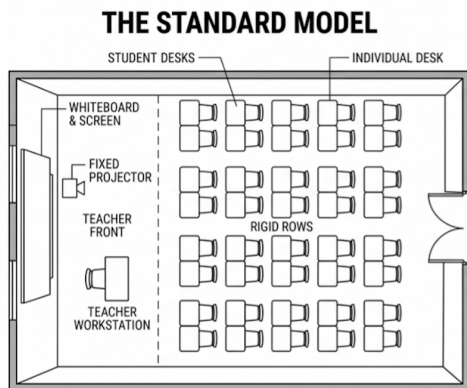
- Opportunities for students to become more skilled collaborators.

When engaged in deeper learning, students engage with new ideas and problems, so they build knowledge and meaning rather than simply being the recipients of transferred information. As a result, students encounter problems in a transdisciplinary manner. One criticism for curriculum in the standard model of education is that it reflects a sample of the declarative knowledge experts in the field know rather than the strategies they use when solving problems. These problems allow students to find more connections to the curriculum when they are studying in this way and the curriculum is perceived as being more relevant; thus, teachers increase situational interest and motivation. This is not possible when information is taught as isolated facts.

Figure 4

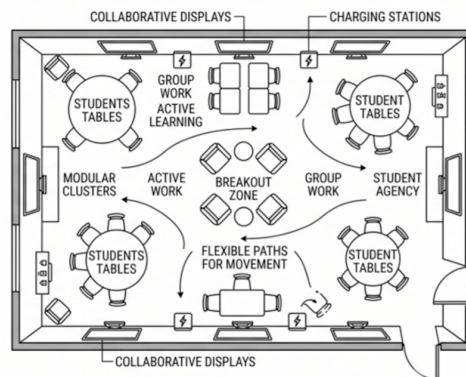
Classrooms for the Standard Model of Education and for Active Learning

CLASSROOM TYPOLOGY COMPARISON: STATIC VS. FLEXIBLE LEARNING ENVIRONMENTS



- Teacher-Centric
- Rows/Lecture Focus
- Static Tech Layout
- Limited Movement

CLASSROOM FOR AUTHENTIC LEARNING



- Student-Centric
- Group & Collaborative
- Dynamic Tech Integration
- Adaptive Environment

Authentic Learning

The standard model of education largely assumed teaching is a tame problem, and that we improve education by more efficiently achieving learning outcomes (through higher test scores). So that curriculum goals could be achieved efficiently, the problems that became learner tasks were de-contextualized; the context of rich information and social interaction from which the problem is derived was removed. While this was done for the purpose of removing complicating information, such de-contextualized problems were isolated from the real-world and have little meaning beyond the classroom. Although such de-contextualizing removed opportunities for students to find connections between their everyday experiences and schooling which is now known to facilitate learning, it is still practiced in many communities. Mehlenbacher (2010) observed, “Over time, our definition of [learner] tasks has generally grown more realistic, meaning we have generally acknowledged that tasks cannot be easily algorithmized or parameterized” (233). By retaining the complexities of problems that become the focus of curriculum and instruction, it is reasoned learners will develop the innovative thinking that is of particular importance in the unpredictable future. Such problems form the basis for authentic learning.

Jan Herrington, Ron Oliver, and Anthony Reeves (2007), scholars from Australia, concluded learning tasks that facilitate authentic learning allow students to generate and test their own ideas in a manner that replicates the rich situational complexity that is encountered by professionals working in the fields being studied. They reviewed research and meta-research conducted around the turn of the century and found that classrooms in which that complexity has been conserved share nine characteristics, and they use those to characterize authentic learning environments.

Based in Real-World Problems

When challenged by students, “Why do we need to know this?” many educators respond by describing situations in which the ideas and skills being taught may be useful once the students have developed them. Teachers in

classrooms where authentic learning is underway rarely have to answer that question. By leaving the details intact as the problems are transferred from the professional world into the classroom, educators preserve the conditions that make the skills and knowledge necessary and students find connections between their experiences and the problems as they gain experience working through—although not necessarily solving—real world problems.

Extended Time to Work

Because real-world problems require days or weeks (or even longer) of effort to sufficiently understand and solve, authentic learning allows students to work on the problems for similar lengths of time. Artificially simplifying problems so that they fit into available time frames may be necessary but does jeopardize the real-world nature of the problems.

Access to Experts

In traditional classrooms, the teacher is the individual who has the most experience in the field, and hence is the community's expert. While teachers are still experts when they teach for authentic learning, they also engage with other experts. For example, I once worked with a biology teacher who had students interviewing physicians, research scientists, and other professionals for a physiology unit. I also worked with a student in grade eight who learned to weld for an authentic learning project, and the assistant superintendent of the district was convinced his sculptures were the work of local artisans.

Access to these experts provides students with different perspectives and understandings of the structure of the discipline as it is applied to real-world problems. In some instances, educators who have experience in the field—for example music teachers who also have performing careers or science teachers who have worked as researchers—may be able to provide such expertise, but authentic learning requires the distinctly different perspectives of both the professional educator and the expert.

Multiple Perspectives

The problems that focus study in authentic learning environments are likely to be wicked and so the multiple perspectives that different individuals and populations bring to those problems are introduced to classrooms. When designing authentic learning tasks, educators will both recognize and encourage students to consider and reconsider the problem from different perspectives, and the planning will not prescribe students adopt a particular perspective. Further, authentic learning makes use of the primary and secondary sources that are available via networks, and so tertiary sources (such as textbooks) are of lesser importance.

Collaboration

Whereas much pedagogy is designed to encourage students to work together, and those methods do encourage social interaction which is fundamental to human learning, Herrington, Oliver, and Reeves define collaboration as social learning that results in a product that could not have been created independently by any of the participants. This represents a more sophisticated view of social learning than simply allowing or encouraging students to work together when completing learning tasks.

Reflection

Authentic learning tasks encourage students to think about how the parts of their solution fit together and the processes that led them to the solutions they create. Further, they are led to revisit their process and solution to assess their strategies and approaches. This process is typically referred to as reflecting on the work, and through those processes, students become meta-cognitive; they think about their thinking.

Access to Scaffolding

In traditional classrooms, both the cognitive structure of the disciplines and the details and applications of these structures are prescribed in the curriculum. In authentic learning environments, the structures are provided by the teachers and other experts, and the students gain experience within that structure by filling in details and exploring applications. For example, a science

teacher may introduce experiments as a tool that scientists use, and then students will study how experts design experiments and they will design their own experiments. As they conduct experiments from real-world problems, students in an authentic science classroom will gain experience with the details of experimental design and data collection and analysis. In this way, authentic learning facilitates coaching and guidance by teachers and experts rather than direct instruction.

Articulation

A part of reflection and a part of collaboration in authentic learning is articulation, and Herrington, Oliver, and Reeves (2007) include original speaking and writing and performing as part of authentic learning. Much articulation in K-12 curriculum and instruction occurs within the scaffolding provided by educators' questions and prompts. While that type of guided articulation can be important as students develop expertise, authentic learning also requires learners to compose their own versions of new understanding and insights independent of expert scaffolding.

Authentic Assessment

In all learning environments, some tasks are completed with the expressed intent that the students' learning will be judged based on their performance. In traditional learning environments, these tasks are typically contrived and have little relevance beyond the classroom. Tests are generally identified as an example of tasks that have little relevance beyond the classrooms. (It should be noted that in some professions—for example those related to information technology—performance on tests is used as a gateway through which professionals earn certifications or licenses. As an adult, I observed my father, who had been a truck driver for decades, studying to earn his license to haul hazardous materials as cargo. While the test covered important aspects of hauling such materials safely and in accordance with relevant laws, once he earned the license, his performance on the test was of minimal importance to his supervisors.) In authentic learning settings, the products and performances used to judge students' learning are like those

produced by professionals working in the field. The products and performances have meaning in the real-world, as well as having meaning in the classroom.

Flat Classrooms

Kathy Davidson and David Goldberg (2010), scholars associated with the MacArthur Foundation's Digital Media and Learning Project, used the term flat classrooms to describe initial attempts in recent decades to design curriculum and instruction around context-rich problems rather than de-contextualized problems, thus it is connected to authentic learning. They identified project-based learning, differentiated instruction, authentic assessment, and cooperative learning as some of the educational practices that preserve context and encourage social interaction in learning tasks. Educators and leaders have observed that efforts to create flat classrooms are sometimes met with resistance from various participants in educational communities, however. Flat classrooms and technology that allows for interaction are mutually compatible; the methods are improved through the application of technology and teachers who adopt the methods find the methods easier to implement. Still, however, Davidson and Goldberg recognize educators have been slow to adopt technology-rich flat classrooms.

Situated Learning

The standard model of education exists in schools. These are physically isolated from other spaces. In areas where attendance at school is necessary, it is uncommon to see many children in the community when school is in session. Situated learning (Lave & Wenger, 1991) is an approach to teaching in which students are more engaged with the society in which they will use the information they are learning than in the standard model of education. Lave and Wenger describe the curriculum in situated learning environment as "legitimate peripheral participation."

Situated learning can exist on several levels and even in isolated classrooms legitimate marginal participation is possible. Case studies in which

students explore real world problems are an example of minimally situated learning. In laboratories, shops, and studios we find situated learning existing in schools as well. Field trips are yet another example of situated learning, but they tend to be relatively uncommon in schools where the standard model of education is practiced.

Apprenticeships are among the practices that most closely align with the principles of situated learning. These find students actively engaged with professionals outside of school for extended times. Typically, apprenticeships are overseen by the school, and students and their mentors work on learning plans with specific goals, so it is not a traditional employment setting. School and employment are generally governed by different laws and follow different regulations, so educational leaders and the professionals who are mentors pay close attention to laws and regulation regarding apprenticeships.

Learning in Settings Other Than School

Despite educators' complaints that students are disinterested learners, humans are active learners about what makes them curious. Johnson and Majewska (2022) define and summarize informal learning as a complex and largely voluntary activity that accounts for most of the learning over a lifetime. In 2009, then again in 2019, Mizuko Ito and colleagues published *Hanging Out, Messing Around, and Geeking Out* a collection of case studies describing how young people, especially, are using technology and digital media to facilitate their own learning. It is reasoned the lessons researchers discover about learning that happens in these settings can influence the formal education that happens in schools.

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. The settings of Rogoff's work tend to be in highly social settings and based in real world problems.

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 finds 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.

Knowledge Building

Scardamalia and Bereiter (2006) contrasted 20th century technology-supported instruction in which technology and digital media was assumed to be equivalent to print-based media to knowledge building. Knowledge building is presented building as a social endeavor in which ideas are improved, and the community comes to more clear understanding of ideas together rather than each individual learning facts. The knowledge built through this form of learning arises through observation and discourse rather than authoritative information. In classrooms designed for knowledge building, the technology provides capacity that is directly connected to the social interaction and information that leads to knowledge. Digital knowledge is permanent, yet editable, so one can quickly and easily suggest improvements to ideas, expand and link ideas, and save all versions of their ideas for continued review and refinement later.

Conclusion

In this section, several of the models for teaching that is contrary to the instruction commonly used in the standard model of education are presented. For school IT professionals, it is essential to understand the rationale for technology that may appear contrary to what they expect. In addition, it should be clear these models of teaching may call for unpredictable technology. Appropriate design may call for technology that was not needed previously or that may have arisen since the last updates and upgrades. By understanding the reasons for these unusual requests, we can be more prepared to adequately respond to educators' needs.

Local Curriculum and Instruction

How Appropriate Design is Communicated

Between any individual teacher's concept of school and what they do in their classroom there is the local curriculum plans and documents. These are intended to ensure students have a similar experience regardless of the specific classroom they attend. In some areas, curriculum is controlled by state governments and regulatory agencies, so local leaders are charged with implementing those plans. IT professionals are responsible for ensuring classroom technology meets the needs of educators who are implementing local curriculum and instruction plans.

In the previous chapter, I described some of the wicked problems of appropriate design. Educators are likely to be interested in the approaches to education described in the previous chapter, and they likely studied them in their preparation to be a teacher. The day-to-day work of planning, designing, and delivering instruction tends to focus on procedures that are planned by local decision-making. The local plans are informed by the concepts decided in the previous chapter but that are more specific. Local leaders decide, for example, if early adolescents will attend schools informed by middle school practices or junior high school practices, which are very different ways to structure student experiences.

The concepts of schools described in the previous chapter define the assumptions that are made about teaching and learning. In this chapter, I describe how those concepts are structured for teachers. It is an unfortunate reality that many local curriculum decisions are contrary to much that is known about teaching and learning. As an IT professional supporting efficacious educational technology management, whose work is grounded in collaboration, you will be responsive to those needs of teaching as defined by the organization through the practices described in this chapter.

Curriculum decisions (what is taught) tend to be made by schools as an organization; all of the students who enroll in biology class, for example, will study the same material. Instructional decisions (how to teach) tend to be made by individual teachers. For IT professionals, this means the configuration requested for one class may be different from those requested by another. It is not necessary to meet every individual teacher's request, but it is helpful to know why they are made so we can accommodate as many as we can.

Curriculum

When describing the standard model of education, I suggested that we are not certain about the nature of the curriculum as we might think. Educational standards are updated regularly, and politicians and philanthropists make curriculum decisions. Even within a group of educators, individual teachers will express differences about the validity of the curriculum. Much curriculum is justified by what seems to be (and is) tautological reasoning. It is very difficult to define curriculum empirically. As a result, the best definition for question like "is this book written at a fourth grade reading level" or "is this question set eighth grade math?" are "a book commonly read by those in fourth grade" or "problems are typically taught to students in grade eight."

"Career and college ready" has been the intended outcome of curriculum of initiatives such as the Common Core State Standards, the Race to the Top, and other widely adopted initiatives. The portrait of a graduate has expanded in many other types of readiness such as "future readiness," "digital readiness," or "life readiness." While these are laudable goals, most researchers would reason these lack internal validity; it is difficult to control the factors that determine the realization of these goals.

Decisions about appropriate design for educational technology are typically made as part of the curriculum development process for a local school or district. Curriculum development is a cyclic process; it is not unusual for certain subjects to be involved in curriculum development during a school year,

then other subjects involved in the next year and the process repeats so that by the time they complete one cycle, it is time to start the first again. This is a reality of the curriculum design the school IT professional must support.

During curriculum development projects, three types of activities are undertaken. First, relevant standards are reviewed. Second, the curriculum is mapped. Third, the local assessment plan is updated. As presented in this book, these appear to comprise a linear process with one step being completed before the next is started. The reality is more complex. The changing goals of curriculum decision-making are required by changing educational standards, new curriculum materials being developed, and old materials being used despite new standards being developed. Also, standards for different subject areas are updated on different timelines; just as updates to the mathematics standards and curriculum has been completed, the languages arts updating will begin.

Standards

As will be described in chapter 10 Laws, Regulations, and Policies, standards are rules defined by experts to guide practice. In the field of curriculum, standards are created by various professional and political organizations. The National Council of Teachers of Mathematics (NCTM) was the first professional organization in the United States to define curriculum standards in 1989. Since then, the NCTM revised its standards intended to answer to the question “what math should students learn?” Other professional organizations for teachers such as the National Science Teachers Association (NSTA), the National Council for the Social Studies (NCSS), and National Council of Teachers of English (NCTE) have also defined standards.

The specifics of how any particular collection of standards are written vary depending on the goals and preferences of the organization, but in general, standards are written on three levels. First, there are overarching goals or principles that are the foundation for the subject matter from the organization’s perspective. Second, there are perspectives on problem solving within the discipline from the organization’s perspective. Third, there are the

content standards which represent the specific topics that should be taught. Typically, standards are organized into grade levels that are used to ensure age-appropriateness of the content. For example, NCTM uses specific grade levels while NSTA uses general grade levels such as primary, elementary, middle school, and high school to organize their standards.

Table 3
Comparing Features of Two Curriculum Standards

Feature	NCTM (Mathematics)	NGSS (Science)
Grade differentiation	PreK–2, 3–5, 6–8, and 9–12	K–5, 6–8 and 9–12
Primary structure	Principles (6 themes) and Standards (10 strands)	Performance expectations built on three dimensions (SEPs, DCIs, CCCs)
"Doing" the subject	Process Standards: Problem solving Reasoning/ proof Communication Connections Representation	Science & Engineering Practices (SEP): Asking questions Modeling Investigating Data analysis
Content types	Content Standards: Number & operations Algebra Geometry Measurement Data analysis	Disciplinary core ideas (DCI): Physical science Life science Earth/Space science, Engineering
Connecting themes	Focused on "connections" between math topics and real-world context	Crosscutting Concepts (CCC): Universal ideas that bridge all sciences
End goal	Mathematical literacy and "Reasoning and sense making."	Scientific literacy and the ability to explain "phenomena" or design solutions.

Examples of Standards

Two examples of standards provide a general overview of the organization of standards. Remember, the goal for IT professionals is to understand standards as dynamic documents that are the foundation for the curriculum and teaching that we support with our systems.

The National Council of Teachers of Mathematics is a leading professional organization for K-12 mathematics teachers in the United States. In addition to the curriculum standards, they publish books and journals for math teachers, hold conferences for them, and otherwise support math education. While their primary focus is on learning for students through approximately age 18, in 2020, the NCTM did publish standards for mathematics educators. Their original curriculum standards were published in 1989, with an update in 1991 focusing on teaching practices and another in 1994 focusing on assessment practices. In 2000, the NCTM revised and consolidated their standards into the Principles and Practices.

The Next Generation Science Standards (NGSS) provide an example of curriculum standards that have emerged from a collaboration of several organizations working closely together. In 2012, the National Research Council published *A Framework for K–12 Science Education*. That work led to a new consortium of organizations including the National Research Council, the National Science Teachers Association, the American Association for the Advancement of Science, and a number of individual states from the United States releasing the NGSS in 2013. Since then, NGSS has become the most influential science education reform in decades, with many states adopting the standards outright or creating NGSS-inspired versions. The NGSS continue to shape curriculum, instruction, and assessment across the United States.

As is illustrated in table 3, both the NCTM standards and the NGSS have common elements, but each reflects the nature of the topic and the preferences of the committees that created each.

Technology Standards

Among the professional organizations that publish standards is the International Society for Technology in Education (ISTE), which is the leading professional organization for educators and IT professionals with interest in educational technology in K-12 schools. ISTE first published standards in 1998 and the National Educational Technology Standards focused on what students should be able to do with computers. Since then, the name was changed to ISTE Standards, the contents have been updated twice, and the organization has expanded the stakeholders for whom it defines standards. When school and curriculum leaders plan and design technology-based instruction (teaching about, by, via, or with technology), the ISTE Standards are likely to be the documents that they are trying to address. For this reason, IT professionals in school should have some understanding of the contents.

As of 2025, ISTE promotes technology standards for students, educators (primarily teachers), educational leaders, and instructional coaches, as well as standards for computational thinking. IT professionals can expect school leaders to reference these standards when making decisions about the appropriate designs to be implemented and supported with the IT systems.

The standards do assume the curriculum is intended to extend teachers' and students' capacity to use IT beyond simply operating computers and developing declarative knowledge and simple skills. ISTE standards promote:

- *Active learning*—Active learning is differently defined by different educators; this point was made in chapter 1 “Concepts of Schools.” All versions of active learning comprise a range of teaching methods in which students are not sitting and listening to lectures, rather they are engaged with the curriculum and constructing knowledge as they solve or attempt to solve complex problems. Most advocates for active learning allow for passive learning when it is needed and for brief periods. Remember, active learning is unlikely the type of teaching done

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in the standard model of education and the technology we manage for these classrooms is different too.

Table 4

National Technology Standards in the United States

Title	Year	Summary
National Educational Technology Standards for Students (NETS•S)	1998	Focused on teaching basic technology literacy and technical skills
National Educational Technology Standards for Teachers (NETS•T)	2000	Outlined the competencies required for classroom teachers to effectively plan, design, and use technology-in classes
National Educational Technology Standards for Administrators (NETS•A)	2002	Guided administrators build infrastructure, managing resources, and implementing technology integration
ISTE Standards for Students (Second Generation)	2007	Shifted technical proficiency to digital tools for collaboration, communication, critical thinking, and creativity
ISTE Standards for Teachers (Second Generation)	2008	Tasked educators with modeling digital age work and learning and assessments
ISTE Standards for Administrators (Second Generation)	2009	Education leaders foster an culture of innovation, systemic improvement, and digital citizenship
ISTE Standards for Students (Current Generation)	2016	Redefines students as empowered learners, knowledge curators, and global collaborators
ISTE Standards for Educators (Current Generation)	2017	Reframes the teacher's role from a presenter of tech tools to a continuous learner, leader, citizen, collaborator, designer, facilitator, and analyst
ISTE Standards for Education Leaders (Current Generation)	2018	School leaders act as equity advocates, visionary planners, and system designers to transform learning cultures through technology

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- *Citizenship*—ISTE advocates that all users in schools understand, promote, model, and demonstrate ethical use of technology and the application of technology to important problems.
- *Collaboration*—Central to our emerging understanding of human learning and to our understanding of how problems are best-solved is the idea that learners and problem solvers work together and incorporate diverse perspectives. Collaboration is typically a component of the strategies that are included in active learning.

Local Curriculum

In the United States, the standards are recommendations only. There is no national curriculum, so the decisions about what is to be taught vary according to the local curriculum plan. In some states, there is a mandated curriculum, but even in the schools in those states, there can be decisions about exactly what is taught and how it is taught in many schools. For these reasons, many curriculum decisions are made by local school administrators; while IT professionals should understand the reality of different concepts of schools, their day-to-day work will be spent implementing the IT necessary for decisions made locally.

Typically, a central office administrator with the title “curriculum coordinator” (or something similar) will serve as the chief academic officer and assume responsibility for decisions about the curriculum and instruction. They will lead committees comprising educators and sometimes other interested parties that create curriculum maps and assessment plans.

Curriculum Maps

Curriculum mapping is the process whereby standards are combined with the interests of teachers and local resources to decide what is taught in which grade. In many cases, local curriculum maps reflect the school-wide adoption of a program or the adoption of a series of textbooks. This is particularly true in mathematics and language arts where a multi-year program

will be adopted, and students make progress through the curriculum as planned and mapped by the publisher. The success of such programs is dubious. It is not unusual for a program to be adopted then replaced with a different one a few years later, and the original program and the new one are based on contradictory methods.

In other cases, the curriculum maps are defined by local decisions alone. I once served on a science curriculum committee where our first meeting was introduced by a new curriculum coordinator who observed that between grades two through seven, students studied dinosaurs in three years. Although that was a time that dinosaurs were very popular among children, the intent of the committee was to expand the science curriculum.

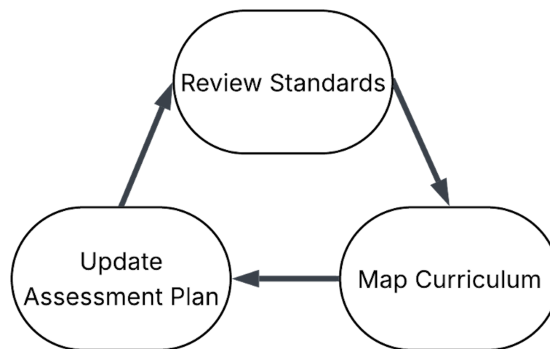
The IT department, more specifically the technology integration specialists, is typically involved in local curriculum decisions. As described in the chapter Local Curriculum and Instruction, technology integration specialists are educators with specialized training in the use of technology in classes. The educators are involved with determining the technology specifications necessary for curriculum and instruction decisions. These may include hardware and software and cloud-based resources. The IT professionals must contribute to ensure sufficient quantities of appropriate technology are available where they are needed and when it is needed.

Assessment Plans

Assessment and evaluation find students and faculty involved in similar activities, but they are different. In both cases, students answer quiz or test questions, write papers, create projects, and otherwise demonstrate what they have learned. The goal of this work when it is assessment is to provide data about students' abilities and to give feedback so they can improve. When it is given as evaluation, it is used to make judgments about their work, and it is used for report cards or other summative reports (Black & Wiliam, 1998). In fact, evaluation is not a widely used term in most educational organizations; rather, it is called summative assessment. What I called assessment to begin this paragraph is now called formative assessment. I have always found those

phrases to confuse students; I believe “assessment” should be feedback given to students and “evaluation” is used to determine grades for report cards. Regardless of my opinion of the practices, and yours too, IT professionals have a responsibility to ensure the school can use technology to accomplish both the local assessment program and those that are part of wide-scale testing.

Figure 5
The Curriculum Development Lifecycle



In the 21st century, it has become expected that educators be “data driven.” Ostensibly, they make all decisions based on relevant information. In almost all cases this data comes from tests. While the reliability and validity of the tests and data are dubious, students take far more tests than previous generations of students did; those tests are often administered via web-based interfaces. The trend to computer-administration is nearly complete for those tests that are widely administered. In early 2022, the College Board announced the SAT would be transitioning to computer-based delivery only in the coming years. IT professionals are expected to support computer-based testing for all purposes and to generate and disseminate reports of the data that are collected via the tests.

High-Stakes Testing

In the United States, high-stakes tests are associated with the standards that were adopted by states under the *No Child Left Behind* act and the *Common*

Core State Standards initiative (Hamilton et al., 2002). The term “high stakes” is traced to the efforts in the early years of the 21st century to ensure that 100% of students passed the tests (a statistically and practically impossible condition to meet). Schools that did not make “adequate yearly progress” towards that goal were sanctioned, thus the results were “high stakes.”

While the original efforts have been replaced, and the exact testing requirements depend on the tests that have been adopted within the jurisdiction, high-stakes testing is still very common. Since their inception, these testing requirements have generally expanded to include more subjects than they did originally, and tests are administered to a greater number of students than they did originally.

For several years at the middle of the second decade of the century (when these tests were first administered via computers), school IT professionals and school leaders were making decisions and installing systems that met the system requirements of the tests they were mandated to administer. Network capacity was improved to meet the requirements and user devices that had sufficient processing and video requirements were purchased and configured. In the years since, technology advances have generally outpaced the advances in system requirements for the tests, so school leaders rarely find they have insufficient capacity to administer the tests.

Because of the importance some interested parties ascribe to these tests, it is not unusual for school leaders to take steps to ensure technology resources be reserved when the tests are being administered. IT professionals may be expected to be present while the tests are being administered to troubleshoot problems, and the system administrators may be asked to limit other uses of the network during testing. For example, public SSIDs may be disabled, or *YouTube* may be blocked on the school network to restrict uses that may interfere with the network capacity needed for testing.

There are two types of tests that are typically administered to students: standardized and standards based. For IT professionals who are designing

systems to administer the tests, there is no difference; devices must be able to establish reliable and secure connections to the servers where the test is housed, user accounts must be created, and testing conditions managed. For the data specialists, there may be differences on the strategies for reporting results.

Just so you don't have to ask the difference once you get into a school, standardized and standards-based tests are differentiated by the comparisons contained in the results. An individual's score on a standardized test is compared to all the others who took the test, so it is reported as a percentile. Scoring in the 50th percentile means half the students scored higher and half the students scored lower. Standards-based tests compare individual's performance to what they were expected to learn. Results of these tests are reported with some variation of "no evidence," "almost meeting the standard," "meets the standard," and "exceeds the standard."

Wide-scale tests are assigned by regulators and results of the test have become the interest of large groups in society. Politicians, parents, and community members want to know the results, even though they are largely unfamiliar with the statistical nuances of percentile ranks versus criterion-referenced benchmarks. Schools are also places where tests such as the SAT are administered, and those tests are digital as well, so schools administering them must meet their requirements.

Diagnostic Testing

There are diagnostic testing protocols that have been incorporated into many curriculum programs that have been adopted by schools; these are intended to measure students' skills in essential fields. For example, a school may adopt diagnostic testing to measure students' preparation for learning to read. The rationale for increased diagnostic testing is that all decisions about curriculum and instruction must be made to create measurable changes in students. Many educational theorists reject this assertion; they claim it makes no sense to measure skills for reading development for students who are already reading or those who are progressing within the normal range of skill.

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Many of these systems are cloud-based, so IT professionals are expected to vet the provider to ensure their standards meet the local policy, support and manage user access to the systems, system compatibility (which may require web browser plugin to be installed), and secure any data that is downloaded from the platform for local use. If the system is not cloud-based, then the expectations of IT professionals change, but data security is always our responsibility.

Electronic Portfolios

If a school does collect data other than test scores, it is likely they encourage students to document learning in electronic portfolios. In schools where project-based learning, internships, and other authentic learning methods are used, students develop skills and knowledge far beyond what can be measured on tests, so students capture evidence of their learning in a portfolio.

Portfolios are commonly organized around the competencies that the curriculum is designed to promote. These tend to be much broader outcomes than are typically found in statements of learning outcomes. Students may be expected to demonstrate how they have become an effective communicator or a skilled problem solver in their portfolios. Electronic portfolios are also widely used in situations in which students are preparing for study or employment in specific fields. For example, art students compile portfolios as do students who must demonstrate their abilities in health care or other skills-rich fields. After the educators have arranged the organization of the portfolio, which becomes a template for the students; students capture images, video, or other artifacts of their learning to customize theirs. Finally, they reflect on the meaning and importance of the artifacts and how it demonstrates their new learning.

In those schools where they are used, electronic portfolios contribute to a more complete and comprehensive evaluation of what students know and can do than those schools that rely only on test scores (Barrett, 2007). Because of the personal nature of electronic portfolios and the fact that artifacts are often images and video, IT professionals in these schools will be asked

to facilitate students' use of their own devices to document learning. Such steps to allow students to use personal devices include opening an SSID for students to connect phones and tablets and ensuring cloud services allow the devices to connect and the files (even large files) to be uploaded. In some areas, policies do limit students' ability to use smart phones in school. In schools where cell phone use is restricted, plans will have to be made to accommodate the need for larger amounts of student images and video for portfolios.

The IT professionals may also be asked to configure the learning management system so that work submitted there can be integrated into electronic portfolios. In some cases, the ability to integrate portfolio is built into the LMS or requires the integration of a separate electronic portfolio platform through a learning tool interoperability (LTI) tool. Other schools whose students create electronic portfolios may decide to use standalone systems.

Electronic portfolios can be an interesting addition to the teaching and assessment strategies in schools. When planning them, teachers often expect that their assignments will be among the artifacts, and they will insist (for example) "students must put a poem they wrote in it," but the purpose of an electronic portfolio is for students to describe their own perceptions of what has been meaningful and what they believe is their best work. The more prescribed the requirements, the less meaningful the portfolios will be and the more likely they are to be abandoned.

Technology in Instruction

As an education technology professional, you will collaborate with the teachers and educational leaders in schools to ensure the systems you support will support the curriculum and assessment plans necessary to meet the intended standards. You will also collaborate with individual teachers to ensure they can meet their instructional goals.

Meeting teachers' instructional goals with technology tends to be an individualized endeavor. A teacher will approach the IT staff with a request

that they and their students can complete a specific project, and in many cases, they will ask for the “best way” to complete a certain project. In this section, I describe some of the commonly encountered instructional uses of information technology.

Four Prepositions

Since IT was first introduced into schools, educators have explored the role digital electronic computers should play in teaching and learning. What has become clear is there is no single role that IT should play in schools. Four adjectives can be used to capture the approaches to using technology that have been developed: teaching about, by, via, and with technology. IT professionals must be prepared to recognize each comprises different types of interactions, and they must be prepared to design systems that facilitate each and to support teachers and students engaged in each. Teaching By Technology

When using test-preparation software, skills-building websites, typing tutors, and similar tools, students are experiencing teaching by technology. For previous generations of technology-using teachers, “edutainment” software was a popular method for teaching by technology. This software found students playing games in which they earned points by quickly answering mathematical calculations (for example).

One of the more popular uses of teaching by technology for educators today is the use of test preparation platforms. These are cloud-based and customizable, so teachers can create class lists, define the content they want the system to present to students, and to set other variables. Students log on to the system and work through the lessons selected by the teacher. Later, the teacher can log on to the dashboard and see each student’s progress. Data specialists employed at the school may also access these dashboards to generate reports for various stakeholders, although access to the data in the reports must comply with FERPA protections of privacy.

Most educators recognize this approach is useful for only a limited type of lessons that can be effectively delivered by technology. Once the teachers or

other educators define the lessons to be presented, the system and its algorithms (including the errors programmed into it and the biases of the designers) determine the experience for the students. These systems generally rely on students demonstrating learning by providing answers to fact-based questions in which the answers can be clearly identified so it can be evaluated by software. These systems also depend on algorithms to determine what happens when students do not provide the expected answers; sometimes they deliver easier questions, sometimes they direct students to sections for review.

The publishers and vendors who produce platforms for teaching by computers seek to take advantage of the economy of scale. Once the system is produced, they can sell it to many schools and the very substantial development costs are distributed over the many clients. For this reason, these platforms tend to be written to address very general curriculum goals, and in many cases, the vendors seek to influence curriculum decisions, so they create a market for their product regardless of the degree to which the lessons reflect what is needed by the students.

Teaching About Technology

Teaching about technology was common when computers first arrived in educational markets. Called “computer literacy” at the time, it focused on teaching students the names and functions of the components of systems rather than how to use them. Although this has largely been abandoned, this was a very reasonable approach at the time as few individuals had computers in their homes and one of the most important aspects of IT was knowing the system one needed and setting it up to function. Whereas computer users today can purchase systems that automate much of the configuration (for example, when I replaced my years-old printer recently, both my Macintosh computer and my Windows PC recognized the new peripheral and installed the drivers without me taking any action), previous generations of computer users needed to what type of cable connected their peripheral and how to install and configure the driver software to make them operational.

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Although teaching computer literacy as described above is not common any longer, many schools continue to teach lessons in which the systems are the curriculum. For example, when teaching lessons about digital citizenship, cybersecurity, and coding, educators are teaching about technology.

Training users how to operate the systems they will encounter is also teaching about technology. Ensuring students know how to use Google Workspace applications, the full text databases available through the school library, and the tools used by math teachers for graphing are examples of teaching about technology within the domain of educators. Ensuring teachers know how to use the student information system, email, and other systems is an example of training within the domain of school IT professionals, and IT professionals are often expected to both deliver training to students, teachers, and other users and prepare how-to articles or videos to support them.

Teaching Via Technology

Teaching via technology describes teaching in which the lesson could be done with or without the technology. The technology may increase the efficiency of some activities, but IT does not influence what students do or how they think about the material being presented.

Consider, for example, a mathematics classroom in which students solve problems on paper. When students review their work in class, the teacher may ask students to show their solutions for all in the class to see. In the 1970's and 1980's, my classmates and I carried the paper on which we had done our calculation to the front of the classroom where we transcribed our solution onto the chalkboard for the class to see. I asked my students to do the same when I taught math in the 1990's (although the board was a whiteboard and students used color markers to write on them). When I was a school technology coordinator, I was asked to purchase a document camera and projector (about \$2000 worth of hardware at the time) so that a math teacher could project images of the paper on which students had performed their calculations onto a screen for the class to see. In that case, the experience of doing math was not changed by the technology as students were performing calculation by writing

numbers and drawing lines on paper. The students and teacher did avoid the time needed to copy the solutions on to another medium, but the students did not engage with math any differently.

Video content is another example of teaching via technology. Whereas video content was displayed to the entire class at one time before computers arrived in schools (and it still is in many instances), students today often have the option of watching video content on their own. In the 2010's many teachers explored "flipped classrooms" in which instruction was delivered via video and students watched them for homework, then class meetings were used to solve problems and apply what was taught via video. There are advantages to teaching via technology that do affect how students learn in some cases. If students can access video content away from class (for example when they are doing homework), they can get additional explanations just at the moment they need it, which is advantageous, but the presentation is still like a lecture, and the student cannot get clarification from a video-based explanation.

Teaching With Technology

Teaching with technology has been called technology integration in many sources. This finds teachers incorporating technology into the lessons they would teach without technology. In addition to adopting technology to present the lesson, teachers who teach with technology often adapt their lessons. They will both make planning decisions about the lessons based on the technology tools available and vary the lesson depending on the capacity of the technology.

Consider, for example, the math teacher who decides to use an online graphing calculator rather than graphing on paper. That teacher may be able to introduce more sophisticated graphs more quickly than those who plot functions on paper, or they may be able to create sliders or similar controls that allow students to see how changing those variables affect the plots.

Of the four approaches to technology-based teaching, teaching with technology is the one that necessitates the greatest adaptability from educators and flexibility from IT professionals. Whereas the other approaches are used for

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lessons in which there are clearly defined educational goals and technology needs, teaching with technology requires design that accommodates many variables including uncertain goals, needs, and customization and individualization of product in which students demonstrate their learning.

One interesting and effective method of teaching with technology is the use of simulations. These are especially effective in mathematics and science education and allow students to participate in otherwise unavailable experiments and demonstrations. Of course, the boundaries between these types of teaching do blur. For example, a biology teacher who uses video to show students footage of underwater ecosystems is probably teaching with technology rather than teaching via technology.

Figure 6

Four Prepositions Describing Technology in the Classroom

The 4 Prepositions of Instructional Technology

Since computers entered schools, their role has evolved into four distinct approaches. IT professionals must recognize these different interactions to design systems that support the specific pedagogical needs of each approach.



Teaching BY Technology

Systems and algorithms determine the student experience, often focused on fact-based, automated lessons.

Teaching VIA Technology

Technology increases efficiency (e.g., digital projectors) without changing the core nature of the lesson.



Teaching ABOUT Technology

The technology itself is the curriculum, covering topics like coding, cybersecurity, and software operation.

Teaching WITH Technology

Teachers adapt and transform lessons using tools like simulations to achieve otherwise impossible goals.



Computers as a Subject

Throughout a student's career in kindergarten through grade 12 education, there are many lessons in which the computer hardware, software (both locally installed and cloud-based), programming, cybersecurity, and related topics are the lesson to be learned. These are all examples of teaching about computers, and sometimes they are taught by regular classroom teachers and sometimes they are taught by specialists, and sometimes by classroom teachers and specialists together.

Programming

Coding, which refers to teaching students how to write computer programs, has a long history of focusing the attention of computer-using students in schools. When computers first arrived in schools, multimedia was not yet possible, and even word processors and spreadsheets were not fully developed, so programming was how students created computers. Beginners All-purpose Symbolic Code (BASIC) was invented at Dartmouth College in 1964 and was used for the time-sharing schemes that allowed multiple users (including students in public schools) to write programs that were executed on mainframe computers (Rankin, 2018). Versions of BASIC were also available for desktop computers, so one of the first uses of computers in schools was to teach BASIC programming.

Coding continues to be an activity taught in schools. It can be its own subject in school (such as high school students enrolled in Advanced Placement Computer Science courses), it can be incorporated into other lessons (such as middle school math students coding with *Scratch* in mathematics courses), or it can be the focus of special events (such as the Hour of Code).

Scratch is a popular platform to introduce students aged eight to 15 to coding (Resnick et al., 2009). Originally released to the public in 2007, the team at the Media Lab at the Massachusetts Institute of Technology that produced and maintains Scratch have released two additional versions, and there have been other related projects such as Scratch Junior which is targeted

at students aged five through eight. Many trace the origins of Scratch to the Logo programming language developed by Seymour Papert in the 1960's (Papert, 1980). *Scratch 2.0* (the version released in 2013) introduced the online version, and most Scratchers (the nickname Scratch users have for each other) log on to the online project editor to select control blocks, set variables, and customize sprites as they design their projects. That editor also allows Scratchers to publish and share their projects so that other can use them or even edit them. *Scratch 3.0* was released in 2019, and it includes support for mobile devices. Especially if you are interested in working in elementary schools, being familiar with *Scratch* is valuable knowledge.

The Hour of Code is a project in which schools host events at which students participate in coding activities. It is not unusual for these projects find students taking “field trips” within the school building. Normal classes are cancelled so that students can have special instruction, listen to guest speakers, and otherwise focus on coding. While Computer Science Education Week (an event encouraged by and sponsored by a collection of organizations and businesses) and Grace Hopper's birthday (Hopper was a programming pioneer) are popular times to schedule events, local organizers may schedule events to meet their school schedules.

While technology integration—the use of technology to teach other lessons—has been the dominant use of technology in education for several decades, there are organizations that have advocated including programming activities in the curriculum. It is reasoned that programming can teach various thinking skills (the evidence for this is not strong) and that programming can demystify technology by giving students experience controlling it. Regardless of the rationale, many students enjoy learning to program.

Digital Arts

Especially in high schools, many art programs have integrated digital photography, video production, and podcasting into the curriculum. In many cases, these courses are taught in studios equipped with photo editing, video editing, and audio editing software. In addition, these spaces may include

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cameras, lights, green screens, microphones, and similar hardware for recording. The intent of these courses is to teach students how to create using these technologies typically used by professionals rather than the devices integrated into other end-user devices.

Because of the expertise needed to configure and customize applications for digital arts, and because that expertise is often held by the teachers of digital arts courses rather than the IT professionals, it is not unusual for the academic department head responsible for the digital arts and the appropriate IT professionals to negotiate a strategy whereby the experts in the digital arts can customize the computers they use while keeping the rest of the system secure.

Makerspaces

Makerspaces have been introduced into many schools in recent decades. In some schools, maker spaces were introduced after wood shops and similar classrooms were removed. In some schools, the traditional industrial arts remain and are supplemented with makerspaces.

In makerspaces, students are encouraged to build solutions to problems. Depending on the age of the students and the interests of the teachers who work in makerspaces, they can include a range of building tools, including 3-D printers, robots, and coding. The Next Generation Science Standards include activities that can be completed in makerspaces.

While the faculty who are hired to teach in these spaces typically have expertise in configuring these devices, in the same way those who work in digital arts spaces have specialized expertise. They work closely with IT professionals to ensure they have the necessary technology and can manage it so as not to interfere with the availability of the devices for students, but also to ensure the network is secure and reliable.

Professional Applications

Many high schools, including vocational or trade high schools, offer a range of computer science, digital media, or business applications courses in which students develop advanced IT skills. It is not unusual to see schools

offering courses that are designed to prepare students for entry level certifications offered by CompTIA, Microsoft, Google, and similar vendors.

The specifics of these offerings depend on the history and popularity of the department and the nature of the local business community. If an art teacher is hired who has special skill in digital photography, for example, the school may offer a course to take advantage of their skill and interest, and IT professionals will be expected to support the hardware and software needs of this course.

Many high schools have computer science departments that offer Advanced Placement (AP) computer science courses which are designed to prepare students to take the exams published by the College Board. While these are promoted as being equivalent to college courses, and students often enroll with the expectation that they will earn college credit for passing the exam, those decisions are made by colleges, and they have been increasingly reluctant to grant credit for passing scores on the Advanced Placement exams.

One of the real challenges for school IT leaders is deploying laboratories or studios in which students are learning how to install, manage and troubleshoot computer networks. Such courses are common in larger high schools or vocational schools that enroll high school students. Planning such spaces is difficult if the students are going to gain experience installing and testing with devices rather than gaining experience only with simulations. Like the professionals who manage digital arts classrooms and makerspaces, these educators need additional tools for managing IT while keeping the rest of the network secure and reliable. There are virtual sandbox environments that logically isolate devices or air-gapped network which physically isolates portions of the network may be more appropriate.

Multimedia

Generations of students have created presentations using a series of programs that combine text, images, audio, and video (thus the "multi" in multimedia). Many trace the beginnings of this type of educational software to *HyperCard* and *HyperStudio*, programs that were available for Macintosh

computers marketed in schools in the early 1990's. Interest in multimedia grew when video cards, color displays, audio cards, and speakers along with the computing capacity to play video became widely available in the middle of the 1990's.

Slide shows created with *PowerPoint*, Google Slides, or any of the popular web-based tools are very widely used in schools. Teachers create them to support instruction, and students create them as projects. While these were originally stored on local drives, students and teachers have adopted the practice of sharing and embedding web-based presentations in virtual classrooms.

Given the ubiquity of cameras and microphones on digital devices, it is easy to forget that the capacity to capture high resolution images, video, and audio is a relatively recent addition to the computing capacity of devices in schools. The web cameras integrated into *Chromebooks* and laptops are used to capture audio and video that is integrated into slides shows, and these presentations are created, edited, shared, and embedded by students in every school.

IT professionals can expect to be asked to support accessibility checkers in the productivity suites they deploy. These tools (which may be built into the applications or may require add-ons to be installed) will identify parts of the presentations that are not compliant accessibility standards according to the Web Content Accessibility Guidelines (WCAG). For example, they will identify missing metadata, missing navigation aids, missing alternative text on images, and other aspects of the files. Some aspects of the files (for example color contrast) cannot be checked via accessibility checkers, and IT professionals will be asked to support other software that does remediate files that are not compatible with accessibility standards.

Video Editing

Among many users, multimedia has been replaced with video, so video editing has increased in importance as an education technology in recent years. Whether teachers are creating video to supplement instruction or students are

creating video to demonstrate learning or student performances are captured on video, there are situations in which the original footage needs to be edited. Many approach video editing with an underestimate of the time needed to produce acceptable video, and many also overestimate the need for professional-quality editing.

There are multiple web-based options for editing video. For example, *YouTube* provides some capacity to edit video that has already been uploaded to the platform. Two challenges that arise from using web-based video editing platforms are the limitations imposed by the applications and the need to transmit video to the platform for editing. Cloud-based platforms tend to limit the size of the clips that can be incorporated into videos created on their sites, they tend to have fewer features to edit videos, and they can have greater latency than video editing software on computers with full operating systems.

On devices with full operating systems, video editing software with far more tools and features than web-based editing platforms can be installed. *iMovie* is a video editing application that is installed by default on Macintosh computers, and it is widely used by that community of computer users. Especially in high schools, there is often interest in teaching students how to use professional video editing software. This software allows for sophisticated editing and can incorporate multiple video and audio tracks, filters, and other sophisticated features.

IT professionals in schools must be prepared to support whatever video editing capacity is necessitated by the curricular goals of the school. Considering the range of instructional goals and the needs of educators, a single video editing tool is unlikely to meet the needs of all users in a school. Middle school students, for example may be able to meet their video editing needs through a web-based platform, but the theatre department in the school may need a professional application to produce video version of their performances.

Video Conferencing

While video conferencing software had been available for several years, it did not gain wide-spread use in schools until the pandemic in the early 2020s.

Since then, schools have largely returned to in-person instruction, but video conferencing remains an option for holding some meetings, some professional training, connecting with remote guests, and otherwise interacting with people at a distance.

IT professionals can expect to play several roles in supporting video conferencing. In addition to providing user devices with camera and microphones, they ensure sufficient network capacity, recommend platforms, provide training, and troubleshooting resources. IT professionals are typically expected to be the experts on using the video platform applications, and we are also the individuals who remind hosts to enable closed captioning or other accessibility tools and to take steps to protect the privacy of participants.

IT's Role in Appropriate Design

According to the framework for efficacious educational technology, educators are the professionals primarily responsible for appropriate design. There is, of course, a role for IT professionals, and of course for school leaders as well. In general, IT professionals and school leaders participate to ensure the appropriate designs are implemented. IT professionals ensure the technology can be configured to allow for the necessary designs, and school leaders ensure reasonableness. Technology integration specialists are the IT professionals who are most active in clearly communicating the technology needs determined in appropriate design to the IT department.

Technology Integration Specialists

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.

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There is a potential friction between technology integration specialists and IT personnel. The specialists walk in both the instructional space and the IT space in schools. When they are members of schools aligned with efficacious educational technology, they collaborate with both educators and IT professionals are perceived as experts in both. However, technology integration specialist should not dictate instructional methods (even those requiring technology) to teachers, nor should they dictate changes to the network or other IT operations. They should be valued sources of information and insight for those who makes decisions in each aspect of the system.

These individuals play active roles as technology stewards (Wenger, Smith, & White, 2009) who advocate for technology solutions aligned with the needs of teachers and their curriculum and their teaching methods. Technology stewards are active in all businesses and industries and work to align technology with users' needs, develop technology awareness to bridge the gap between organizational practitioners and IT professionals, and ensure technology is adapted and becomes everyday tools for practitioners.

These individuals also serve as mentors. Mentors are those 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 they 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 to 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 them 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-Günbatır, 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.

Professional Development

In *A Typology of Professional Development* (Ackerman, 2020) I reasoned there are three types of professional development that involve the IT department in schools. These are variations on activities designed to ensure educators and others in the school can use technology. The fact that I described this as a typology suggested that, like has been described for any learning activities in schools, these vary depending on the intended outcome and IT may be involved in all types on a regular basis.

In the research I reported in the chapter, there were three dimensions that are used to differentiate three types of learning for adults. First, is the focus on technology. It may seem obvious that any professional development that involves technology, but some types of professional development focus exclusively on technology and in other types of the technology is marginal. Second, the source of the expertise. This seems consistent with my framework of efficacious education technology with different professionals responsible for design, configuration, and implementation. Third, the role of the student. It might seem that students are at the center of everything that is done in schools. This not always true. Typically, advocates who claim their recommendations are “for the best of the students” are the least concerned with students. In my professional development typology, I suggest we are clear about the role that students are to play in the activities.

Training

Training is the type of professional development in which technology is the exclusive focus. Expertise comes from technicians who are very adept at using the technology, be it hardware, software, or a web interface. When educators participate in training, there is little focus on students.

An excellent example of a situation in which training is necessary is when a new student information system (SIS) is introduced. In this situation, even the most technology-savvy educators will find the technology unfamiliar. As a result, they would be very inefficient if they went to do the most familiar

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tasks on the new system. When they meet for training on the new SIS, they are concerned only with the specific technology and its operation. In many cases, the training is supported by the local IT professionals, but the main source of information comes from the vendor. Those individuals are the most skilled and can troubleshoot difficulties.

In training settings, there is not focus on the students as can be evidence by the fact that training is often offered to broad groups of educators. It does not matter if one teaches mathematics or science, both need to be able to report attendance, configure gradebooks, manage assignments, and report grades with the SIS, and this is what they are trained to do.

Planning

Planning is the type of professional development in which technology takes a reduced role, educators are the primary source of expertise, and the learning is intended to support students. When teachers are engaged in planning, the IT professionals will be ancillary and may be represented by a technology integration specialist or some other representative from the IT department whose job is to report back to the IT department to determine if the technology can be properly configured to bring the plans into reality.

Whereas in training, technology is decontextualized (it is used by many educators), in planning the technology becomes contextualized as educators have specific goals they want to achieve. Planning is an essential first step in appropriate design, so educators are the leaders of planning. Although planning is designed to meet the needs of students, it is done with no student input. Planning can be seen as educators' best guess as activities that will lead to the technology-based teaching. It relies on experience, but every group of students is unique, so plans must always change.

Design

Designing is the professional development activity in which the initial plans are revised to reflect what was learned when the plans were implemented. The focus often changes back towards the technology as

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educators give feedback about how the technology worked. They recommend changes that will lead to most efficient operation of the technology when it is next used and changes that will make it more effective. Design tends to be a collaborative process as educators and IT professionals brainstorm possible configuration and interface changes that will improve the lessons.

Table 5
Training, Planning, and Design

Dimension	Training	Planning	Designing
Primary Focus	The Technology itself: Decontextualized mechanics and system operations	The Lesson Plan: Contextualized tool integration to support goals	The System Iteration: Collaborative configuration and interface refinement
Source of Expertise	Technical Experts: IT staff, software vendors, or system engineers	Classroom Educators: Teachers and curriculum directors	Collaborative Synergy: Shared brainstorming between teachers and IT staff
Role of the Student	Excluded: Disconnected from student profiles; identical across all user groups	The Target Objective: The focus of the plan, but absent from active input	The Informational Anchor: Student feedback directly shapes the system revisions
IT Department Role	Primary Lead: Direct systems instruction and troubleshooting support	Ancillary Advisor: Vetting technical feasibility of educational proposals	Active Partner: Adjusting systems based on live classroom observations

Compared to the other types of professional development, the role of students is unique to design. When training, students are generally not

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involved; the technology is the same for all teachers regardless of the students in their classrooms. When planning, the students are the focus of the plans as the educators prepare for a specific group of students. When the professional development has been properly designed, it incorporates the feedback of the students, so—while they are not likely to be present—their ideas are. Feedback can come from various sources, some direct and some indirect. In my experience, the best feedback comes from technology integration specialists who are in the room when the lesson is underway and who observes what is happening and has conversations with students and teachers as the lesson is underway.

A technology integration specialist who documents what happened in this way brings important insights to the design sessions preparing for the next iteration of the project. Their insight informs the same lessons or similar lessons and focuses on the operations of the technology, the nature of the materials, and the organization of the activities.

Part 2: Proper Configuration

Part 2 of the book focuses on aspects of schools that affect the proper configuration of systems. We begin with a look at the people who are IT users in schools and the unique characteristics of those populations. Next, we focus on end-user devices (which users physically touch), explore network infrastructure (which is essential to users, but untouched by them), and finally investigate cloud resources (which no one touches, but everyone interacts with).

School Users of IT

Bridging Appropriate Design and Proper Configuration

All organizations have users who interact with the IT, but school users have characteristics that make their IT needs unfamiliar to those with experience managing IT for adult users. We investigate the nature of school users and explore some of the special considerations for managing IT in organizations with young users.

Compared to information technology users in business, IT users in schools are much different. They bring different skills to the IT they use; they need more flexibility in what they do and how they do it compared to business users, and their needs change over time. These characteristics arise from the facts that students have emerging literacies; it is not unusual for primary grade students to be only learning to read and the keyboard is new to them, so many computer interfaces and input options (including typing) may be very difficult for students who need to use them to interact with devices. Even with clear curriculum guidelines, teachers and students may have different information and computing needs than teachers and students in similar courses, and even a single teacher's students may have different needs depending on the lessons they are studying. School years are also periodic. Just when all the elementary school students are becoming familiar with the technology and they are becoming facile using it, the school year ends, and teachers (and IT professionals) must prepare for a new group of technology newcomers.

It is important for all IT professionals who work in school to understand the nature of the users and their specific needs. Every decision made and every action taken by IT professionals (regardless of their role) affects end users either directly (by providing troubleshooting, training, and other support) or indirectly (by selecting, installing, and configuring systems and interfaces). As will be described in this chapter, the unfamiliar IT needs of school users and

the limited capacity of large parts of the school populations to use technology can pose difficulties for IT professionals new to schools.

Assumptions about the users' capacity to operate the devices, adapt to changes, and operate the systems effectively all affect how systems are designed. For those who have experience managing IT in organizations where all the users are adults and those who have completed typical IT programs in schools (including trade schools, community colleges, and universities) make very different assumptions about IT users than are true of school users. Some of the strategies that produce effective systems in other organizations are less effective in schools than they are in other organizations.

Comparing School Users and Other Users

The careful reader will notice that I am beginning this chapter with some assumptions about the typical IT users in organizations other than schools. I begin with these users to introduce the characteristics of humans that seem to affect their abilities to use computers. Many IT professionals have not previously contemplated this aspect of IT system planning. I find the differences between IT users in other organizations and IT users in school can be summarized in five characteristics:

- *Business users tend to be competent in basic skills such as literacy.* When building systems for business users, IT professionals can assume the users have some basic digital literacy and can operate a computer, they can read the screen and directions and interact with the graphical user interfaces so they can accomplish the tasks they were hired to do. When referring to school-aged learners, I like to use the term “emerging competence” to characterize students. As they become more competent readers and writers, they will become more competent users of IT as well.

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- *IT users in businesses tend to have clear and specific needs and equally clear and specific IT requirements.* Business users need certain software and to access specific data to complete their assigned work. If the hardware and connectivity are sufficient to run their software and access their data, then users are satisfied. Members of the accounting department need access to applications and permission to edit financial data, but they do not care if they cannot edit video on their workstations (for example). In schools, many different users with much different software needs may use a specific computer during a school day. The same hardware used by students to run the accounting software for business class during one block in the schedule may be used by students in the digital arts class to edit video during the next block. As cloud-based computing and internet-connected notebooks have become popular, the need for school IT professionals to manage different software for different student users has been reduced. There do remain situations in which teachers cannot accomplish their curricular goals without sophisticated technology, however, and they cannot always predict the systems and IT capacity they will need.
- *The IT needs of employees in business and industry tend to be task-based,* whereas the IT in schools must be sufficiently flexible to allow for interest-based uses. The information sources that must be accessed and the applications provided (on the cloud or on the machine) vary depending on the interests of the student and the instructional choices of the teachers. A further reality of deploying IT systems in schools is that the best-made plans are only plans; many educators do not really understand what they need until they experience it with students, so teachers sometimes ask that systems be reconfigured after IT thought the job was done.
- *In business and industry, users are selected for the role.* Employees have selected themselves for the work (by applying) and they were selected for the position (by being hired). Both gateways ensure those who use computers for their work have the necessary skills or the ability to gain

them and are motivated to learn and use the systems. If this proves to be not true, there are options for the employer and the employee. If training or other support does not resolve the problems using the computers, the employee can be removed from the position. For the public schools I assume that most readers have interest in serving, attendance is compulsory, and schools are obligated to provide education to all students. For these reasons, IT professionals in schools must accommodate a wide range of users, and schools in which a student is denied access to the IT they need may violate that individual's right to an education.

- The final fundamental difference is the *relative stability of business users compared to school users*. In schools, users' skills change over time in a periodic way. The students who struggle to use keyboards early in the school year, become more facile as they gain experience. When the next school year begins, those students are replaced with others who lack the experience. As curriculum changes, the IT needs are likely to change as well. Teachers who are introduced to new teaching methods and resources are anxious to try them. Families move into town and their children have different needs from the other students. All of these are situations in which IT professional must vary from their original plans to meet unanticipated needs.

The differences between IT users in K-12 schools and other organizations are largely based on variability. In organizations other than K-12 schools, IT professionals can predict the skills of the users and their IT needs within clear and narrow bounds. In schools, IT professionals must provide IT for a diverse population of users who have diverse interests and IT needs.

The Different IT Users in Schools

As we look at the different types of users of information technology in schools, look for differences between school users and the characteristics of adult users as described in the previous section. Some of these populations are more like typical adult users outside of school than others, but some are very different.

Students

Students, of course, comprise the greatest number of IT users in schools. When considered together, K-12 students represent a group with very disparate skill sets and needs. School and technology leaders must consider the nature of the students and their learning needs (as well as the teachers' needs that are grounded in their students' needs).

The youngest students have emerging literacy and numeracy skills, and their hands are too small to fit on full sized keyboards in the manner they are designed. Even if their hands could fit the keyboards, they are not yet typists, so their ability to use keyboards for even the most basic task (entering a complex password) may be beyond their abilities; or at least beyond their abilities to do without frustration. They do tend to be curious IT users and anxious to learn to use the devices they know are used by others. The youngest students' use of IT tends to be highly prescribed by their teachers. They often use web sites intended to facilitate learning of academic skills, and some teachers integrate computer devices into the activity centers in their classrooms. Many primary teachers are cautious about using IT in their classes, as there are many other valuable and necessary skills that students must learn especially at this age.

While the youngest students in schools are just learning to read and write, the oldest students are adults (most students turn 18 during their senior year in high school) and are likely to be engaged in independent projects and to have the need to gain experience using the same software that professionals

use. Older students tend to be creators of information with school IT as well as consumers of information. In addition, these students tend to self-select into certain courses, and many schools have added independent projects as graduation requirements in recent years. The IT professional may find students complete “internal internships” by learning entry skills alongside and with active mentoring from the employed IT professionals. The specific resources they use depend on their plans for post-graduation as well as their course work.

Most schools do not have the diversity of students using computers that I managed in that school described in the box, but the students’ and teachers’ needs are the conditions to which school IT professionals must direct their work. IT professionals cannot ignore them when making IT decisions.

Teachers

Teachers are the second largest number of school IT users, and they are the users who have the most diverse IT needs. In addition to using computers for instructional purposes, teachers use their devices to create materials, manage student data, and complete school operations tasks. In addition to their work-related tasks, most school acceptable use policies allow teachers to use their school-owned devices for professional tasks not directly related to their jobs. The list of such activities includes completing courses for credit which are necessary for recertification or for advanced degrees, participating in professional organizations, and engaging in personal learning activities. One of the challenges for school IT professionals is teachers’ (and other adults’) use of school-owned devices for personal purposes. While none of us wants to be obligated to “save my pictures before you reimaging my computer,” no IT professional wants to be the person who deletes personally important files.

In general, educators use whichever productivity suite is supported by the IT professionals to create classroom materials, such as worksheets, study guides, and presentations. Increasingly, Google Workspace files are the dominant suite used by educators. In addition, they use whatever learning management system is supported to extend and enhance their lessons with

virtual classrooms. Managing classroom activity requires they have robust and reliable access to the student information system as well. Whereas previous generations of teachers kept paper copies of attendance (and sent hand-written lists of absent students to the office), today's teachers mark attendance on the online student information system and office staff see the report almost instantaneously. Further, they access human resource systems and documents, requisitions, and other operational systems and documents via their school-owned devices. In these needs, educators are very similar to the IT users in other businesses and industries as they are well-known and predictable.

Meeting the IT needs of teachers is complicated by several factors. First, teachers do not often have the language to accurately describe what they want or need. Their difficulty in describing IT systems affects both their abilities to communicate how systems should be reconfigured to meet their needs as well as their ability to describe malfunctioning systems. For IT professionals, this means they must listen carefully and actively. In addition, they must repeat back to teachers what they are hearing. Often, clear communication requires that the teacher demonstrate exactly what the system is doing that is problematic.

Second, teachers cannot tell if the systems function in the manner they anticipate until it is actually used at scale with students. In most IT design projects outside of school, the use case is relatively well known, so the progression from planning and specifying system requirements to proof of concept through testing and ultimately to production can be done in situations that closely resemble the end use case. While such testing can be done on a limited scale in schools, the unanticipated circumstances that are introduced by students can cause the most carefully planned IT systems to fail "in the wild." IT professionals must be prepared to redesign systems and projects in response to what educators discover when they use IT with students.

I once coached a technology coordinator who was fond of saying, "I built what they asked for, if they asked for the wrong thing, that is not my problem." I tried to get him to realize that indeed it was his problem. The money the

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school had invested in the devices and software; and the time he and his staff had spent was all wasted when the systems remained unutilized or underutilized. Careful listening to understand educators' needs and ensuring the final product is what they need and not what you or they thought they needed before they started are essential skills for IT professionals working in schools.

A third-grade teacher came to me one day when I was serving as the technology coordinator in the school where she taught. She said, "There is no voice on the computers in the lab." At the time, voice to text was beginning to appear on some systems, so I started explaining that these were older machines (they were repurposed desktops from a local company, and we had installed Linux on them) and I would investigate what we could do. She interrupted me and said, "No, there is no voice on them." It took me about 5 minutes for me to understand that what she really meant was that there were no speakers. She wanted her students to use a reading program in which they had to hear what animated characters were saying. I suggested she get her students headphones so they could listen themselves.

Third, many teachers seek flexibility in their classrooms. For several very valid reasons, many teachers vary the physical organization of their classrooms during the school year. Elementary teachers use "centers" and these often change depending on the time of the year or the availability of resources. Others change seating arrangements depending on the units they are studying, and others vary classrooms to introduce novelty. IT professionals must be willing to accommodate teachers' need for flexibility and understand these changes are likely to be rooted in valid teaching needs rather than whim.

Teachers and IT professionals often find they have much different goals and needs when it comes to IT systems. Teachers need flexibility and adaptability, but IT professionals know that flexibility and adaptability can result in systems that are unreliable and unsecure, so they are reluctant to build such systems (Tondeur, 2016). Time is limited, and IT professionals seek to

build systems when demand is low during the summer. Teachers may discover unanticipated needs only after the school year begins, so they may request changes after IT professionals have completed the upgrades, updates, and changes they thought were needed. Educators may also request quick turnaround times on IT requests. For the (typically) understaffed IT staff in schools, unanticipated changes and short timelines can be frustrating and can delay other projects.

Just as teachers must accommodate to changing instructional needs with short-term changes to their practices, school IT professionals must be prepared to make changes to their systems with less notice than they would like. This does not mean that IT professionals must make every change a teacher asks for, but it does mean they must engage in discussions and adopt reasonable timelines for changes deemed necessary for teaching and learning; occasionally, teachers will appeal to school administrators and these must be accommodated to the extent systems remain secure, reliable, and robust.

Administrators

School administrators are drawn from teachers (in most jurisdictions it is necessary to have been a teacher before applying to be a school administrator). While they are educators, their role is much different from teachers, and their technology needs are very different as well. Communication and data are key to the school administrator's work, so access to those systems must be reliable and secure on their devices. Their uses are more like those business users we are familiar with as IT professionals than they are like teachers.

Operations Professionals

Schools also employ a range of people who perform jobs in schools that are very similar to those in business and industry. Schools employ accountants, human resource workers, and building managers (for example) and they do tasks and use similar tools as those who do the same job in other organizations.

Even IT professionals in school use the same tools to manage school IT as those who manage IT in other organizations.

IT Professionals

Because the devices that provide local area network and internet access in schools are the same as those installed in other businesses and industry, many of the IT roles filled in schools are similar to those in other organizations. Because the devices are the same, IT professionals perform many similar roles as well. In schools, we find network administrators, desktop support technicians, and data professionals. There are, however, other types of IT work in schools that are not found in other organizations. Schools are also known to be organizations with under-staffed IT departments. As a result, it is not uncommon for individuals to play multiple roles, and it is also not uncommon for individuals to expand and enhance their technology skills working in schools and to gain experience in new roles. This is one reason school may be excellent places to start an IT career.

One of the realities of working in schools as an IT professional is that other people who work in school often do not differentiate technology roles. IT professionals recognize this is not unique to schools. When someone from “IT” appears, they will be asked to troubleshoot or resolve problems they were not expecting and that they are not prepared to resolve. IT professionals find it necessary to tactfully explain that they have higher priorities at the moment or that they do not have the skill or the authority to solve their problems. Further, IT professionals sometimes find it necessary to explain why some problems have not been resolved.

The IT departments in school comprise a wide range of professionals who are managed by the chief information officer. Each IT professional applies specific expertise to fulfill specific roles for specific audiences. Schools are organizations in which the titles applied to IT positions are very inconsistent. In some schools a “technology coordinator” may serve as the chief information officer (as I define it below); while in a nearby school, a technology coordinator

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may serve as a technician. For this reason, clean and accurate job descriptions are necessary to ensure qualified applicants apply and are hired.

Table 6
IT Roles in Schools

IT role	System	Function filled	Primary audience
Chief information officers	Entire IT system	Advocate and manage	All users
Technology integration specialists	Teaching	Design and support	Teachers and students
Data specialists	Educational data	Generate reports for	School leaders and regulatory agencies
Technicians	End user systems	Repair	Students, teachers, leaders, staff
System administrators	Network	Configure and manage	Local area network and internet connections
Webmaster	Web presence	Publish and post	External audiences

Chief Information Officer

It is only recently that educational organizations have adopted the practice of using “c-level” titles for those in management positions. The superintendent of schools is typically recognized as the chief executive officer (CEO); that individual manages and leads a team of senior leaders, such as the chief financial officer (CFO) who is responsible for the business functions of

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schools, the chief academic officer (CAO) who is responsible for all aspects of teaching and learning within school, and the chief operations officers (COO) who is responsible for facilities management and similar functions, and the chief information officer (CIO) who is responsible for all aspects of the information technology systems within the school. These and others comprise the senior school leadership team, and these individuals typically work in the central office and are responsible for multiple schools in a school district.

Of course, no c-level executive managers work and lead in isolation, so—at the highest level—decisions are made to satisfy the needs and limitations of the entire organization. The c-level manager is responsible to both advocate for the needs within their area of leadership, then to implement decisions within that area. 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 responsibilities assigned to the CIO, perhaps none is more important than those involved with installing and upgrading information networks and securing them because of the nature of the data stored on them. The CIO also advocates for financial and human resources to maintain those networks and supervises the professionals hired to manage the network and all other devices.

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, so educators and leaders 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 with little regard for the effects on teaching and learning. As CIOs have been integrated into technology decision-making in schools, there has been a shift towards making technology decisions for teaching and learning reasons, but that is not yet systemic.

A colleague whose experience was as a teacher attended the first planning meeting of the search committee for a new CIO. Afterwards, he

observed, “I thought we wanted someone with strong technology chops, but we have experts in that on the team. We want a good manager.” I agreed and told him they were not going to get it at the advertised salary.

The individual who serves as the CIO in a school is likely to have qualifications similar to the others on the senior leadership team. School CIOs are likely to have advanced degrees and years of experience managing technology; as the team of IT professionals becomes more diverse, this individual provides direction and leadership more than they spend time configuring devices or troubleshooting problems. When necessary, however, this individual will be found assisting in whatever IT emergencies arise. Ideally, the CIO will have experience working in schools as well, but many hiring committees opt for individuals with technology experience over school experience.

Technicians

Technicians are the individuals who have one of the most important roles in school IT system operations; these individuals are the face of the IT department to most members of the school. A technician is likely to spend their day troubleshooting and repairing end-user devices including desktop computers, laptops, Chromebooks, printers, and other peripherals. Because these professionals spend their 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 and teachers.

On those staffs with multiple technicians, the group can be very interdependent; they collaborate on solving problems and they share what they have learned about the systems and the users of systems. By documenting the repairs that they make (ideally in a ticketing system), technicians contribute to the emerging knowledge of the IT system and help identify those devices that need to be replaced. As professionals who understand IT and who observe users interacting with it the most, technicians are also the first to identify potential

problems that are emerging and unmet needs that the CIO and other professionals must plan to address.

Technicians may be hired with a wide range of qualifications. One can develop the expertise they need to be a successful technician in many places other than traditional higher education. Many school IT technicians are hired and begin work as they are completing their education, or they complete formal education or earn industry credentials while working.

The CIO plays an active role in ensuring the technicians who are working in the school receive the professional courtesies and the on-going support they deserve. Good CIOs support technicians as they develop their knowledge of technology, and they serve as mentors and models as technicians develop customer service skills and professional dispositions.

System Administrators

Once computer networks are installed and configured (usually in consultation with external engineers and technicians), system administrators employed by the school ensure the networks 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 the continued health of the local area network.

Among the specific responsibilities of 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. As cloud-based systems have become more common, one of their most important roles is user management which includes ensuring single sign-on systems are connected and functioning. 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 introduced when networks are changed. In general, if changes are made to a device that contains or manages local area network traffic, it is the

system administrator who performs the task. This individual will also work closely with technicians to ensure that user 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.

Data Specialists

Schools store vast amounts of data in sophisticated databases. The expertise necessary to prepare and run queries of the database so that questions regarding correlations and performance can be answered requires much expertise. Often this work includes creating scripts that produce tabular and graphic reports that are used to support decisions made by school administrators and teachers. In addition, regulatory agencies have increased the data reporting requirements that have been enacted in many jurisdictions that have accompanied enacted since the beginning of the 21st century. As a result, schools have begun hiring data specialists as the amount of data and the sophistication of the databases has increased. The need for this specialist arises from both the skills necessary to manage the demographic, health, behavioral, academic, and other information that is housed in sophisticated databases and the increasing demand for data-driven practices.

These professionals represent one of the first ventures into the field of educational data analytics by schools (Agasisti & Bowers, 2017). In this field, educators seek to apply the methods of data science to predict student needs and performances. It should be noted that advocates for data analytics argue these methods hold much promise for improving education, but those claims have not been documented and observed by scholars in the field (Qazi & Pachler, 2024). Regardless of the degree to which the data are affecting teaching decisions and long-term and desirable learning outcomes, schools are

expected to gather and use data so the need for data specialists is expected to increase.

Webmasters

Almost every school maintains a web presence. These sites serve as an important venue for sharing information with a wide range of internal and external audiences. Those who are responsible for managing school web sites know the most important information that can be posted in the cafeteria lunch menu. Most school web sites provide information and announcements about curriculum, staffing, athletic and extracurricular events (including practices and rehearsals and meetings), governance, and other school activities.

Whereas teachers often maintained classroom web pages in previous decades, those have largely been replaced with Google Classrooms (or a full learning management system) or a page integrated into the student information system. These are spaces where students find resources and assignments, parents and students can see grade reports, and all can access the classroom news and announcements posted by the teacher. Once these spaces are configured, school IT professionals, including the webmaster will not usually post information on classroom spaces.

Many schools are integrating other platforms into their web presence as well. Often interscholastic athletic leagues will ask (quite insistently) that all members use the preferred platform to set schedules. These schedules can be embedded in the web pages of member schools, and it can facilitate reporting of standings, scheduling of officials, and otherwise managing the participation of school team in the competitions. As only one or two individuals in the school need access to post to these sites, they usually handle that without intervention from IT professionals. Once the web master has included the embed code for the schedule in the school web site, changes made by the athletic director automatically appear on the school web site.

One of the more challenging aspects of managing a school web presence is handling images of students. This is especially true on social media. Once images are posted to the web or to social media, the person who posted it loses

all control of it. Some maintain that once consent has been secured from parents, then school employees can post images for any purpose. While this may be legally defensible, it can be argued that children cannot give consent and they are the individuals who may be most at risk because of information or images shared on the Internet, so all adults should be very cautious when posting images.

Public Users

Schools are places where the public is occasionally invited. Some events that find the public on campus place no demands on IT systems. Audiences at athletics events, concerts, and other performances do not expect to have access to wireless networks, for example. Other events may find individuals or groups from outside the school community that have valid reasons for connecting their devices to the school's network:

- *Consultants* from local service agencies may participate in individual educational plan (IEP) meetings or they may provide services to students and find it necessary to connect to internet-based testing instruments or instructional materials.
- *Presenters at workshops* or training events many need to connect to internet-based systems. For example, trainers from the vendor providing the student information system may need to connect to cloud servers.
- *Educators from other schools who are attending professional meetings* or conferences held on campus may need to access their professional email or Google Workspace files during the event.
- *Students from other schools* who are participating in educational events held on campus may need access to the internet during the event. For example, students attending a robotics event may need to download software updates for their robots during a competition.

- *Faculty, staff, and students* may bring their own devices into the school for their own use or for auxiliary use in classrooms.

In each of these situations, it is necessary to connect devices that are not owned by and configured by the school's IT professionals to the school's network. This does pose a risk to the school's networks as they cannot be sure what software is running on the devices that others connect. If the network is improperly configured, then these devices may introduce malware or other threats to the school's network, but skilled system administrators can minimize the risk. Before allowing such access, any IT professional will take steps to ensure such access does not add any risk through proper isolation of the public network.

Special Considerations

Schools are filled with children. Lots and lots of them. Because so many of the IT users in schools are children, which is a population deserving special protections, several wide-ranging national laws in the United States provide guidance and direction for school and technology leaders when they design policy and procedure, and there are also other important considerations that provide indirect guidance for school and technology leaders. Anyone who seeks to work as an IT professional in schools must be aware not only of the requirements of these laws but also the rationale behind them. Ensuring compliance with these laws and regulations is an essential step toward ensuring IT is reasonably implemented.

FERPA

Most IT professionals are familiar with the need to keep data secure. In some industries this is necessary for regulatory purposes; and, in all industries, it is necessary to protect proprietary information and to protect clients' information. In schools, the importance of privacy takes on special importance

because of the age of the individuals about whom the information is kept and the nature of the information that is kept. The Family Educational Rights and Privacy Act (FERPA) is law in the United States which is intended to safeguard sensitive information about children in schools. FERPA details who is allowed access to information kept by the school and the conditions under which the information can be stored. The law does specify the rights of students, and their parents if they are under 18 years of age, as well as the steps school officials are expected to take to protect information. Those whose privacy or rights have been violated can file a complaint with the US Department of Education and legal action is possible.

FERPA was originally passed in the 1970's when print continued to dominate school data, and a school's data could be protected by restricting physical access to the paper files. One challenging aspect of FERPA compliance in schools today is the reality that data systems are often stored on cloud-based systems provided by vendors. In that situation, it is difficult for the parents or the school to have control over the data stored on their systems. It has been suggested (Zeide, 2016) that greater regulatory control over the vendors that provide data systems used by schools may be necessary to protect data in the manner intended by the law.

To ensure they comply with FERPA requirements, most schools require all employees (including IT professionals) to attend training at which local expectations are described. They also protect the school by having employees acknowledge they received the policy training.

While schools may interpret FERPA differently, there seems to be agreement (at least in the dozens of FERPA training sessions I have attended) that FERPA protects a wide range of information, including that which school employees learn accidentally. For example, a school employee who sees a friend in the store and says, "I saw Johnny get into a fight at school today and he was suspended," has violated FERPA. They identified a student and shared information about their behavior and the consequences of it, and the recipient

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of the information was not entitled to know it, nor were the many other people who may have overheard the story in the store.

Table 7

FERPA When Originally Passed Versus FERPA Today

Dimension of Comparison	Physical Records	Modern Data Systems
Record Medium & Storage	Paper records kept on-site locked metal filing cabinets on school premises	Cloud-based databases on remote servers managed by private third-party providers
Accessibility & Portability	Low accessibility	High portability and searchability; records digitized and searchable
Sharing & Transmission	Required active human intention and physical effort	Seamless, automatic, and continuous data flow
Security & Permeability	High physical effort reduces potential for unauthorized access	Digital repositories make data vulnerable to identity theft, malicious hacks, and accidental public exposure
Primary Purpose & Utility	Static administrative and educational evaluation of specific students	Predictive and probabilistic analytics used for automated tracking, profiling, and forecasting
Commercialization & Value	Negligible commercial interest	High commercial utility
Oversight & Control	Direct oversight by educational actors	De facto "virtual oversight;" private vendors hold records on remote servers

IT professionals have an unusual level of access to classrooms and data. When an IT professional is in a classroom and sitting at a computer, they are “a fly on the wall.” Teachers and students largely proceed as if there is no one else there. They gain an unfiltered view of classroom actions and interactions, and some of what they observe must be protected according to FERPA. IT professionals also have access to data systems containing protected data. While the student information system should have protections to prevent a technician from accessing grades, a teacher may ask for help resolving a technology issue when they are logged in to student information system and working the gradebook.

What one observes in data systems, classrooms, and schools must be kept confidential; the teacher who shows their gradebook to an IT technician while getting help has violated FERPA. The IT technician who does not share that information with anyone or who does not treat the student differently has not violated FERPA. They have minimized the damage done by the original violation and they have not violated FERPA themselves which both protects the privacy of the students and minimize the liability due to the original violation. The one exception, of course, is if there are situations that are unsafe or potentially troubling. IT professionals have the same responsibility as anyone, especially adults, to prevent and report those situations.

Now that projectors are found in almost all classroom and those tend to be connected to the single device assigned to the teacher, it is not uncommon for the teacher’s gradebook to be displayed accidentally when the projector is turned on and the gradebook is open on the computer. While most teachers are aware of the potential and will close their gradebooks, those steps may be forgotten. Many technicians have a question they will ask before turning on any projector and they try to make it a joke. One of my former colleagues would always ask “what is going to be on the screen when I turn this on? I’m not going to give away the winning lottery numbers, am I?” when the lottery joke got tiresome, he would say “I’d hate to show everyone your secret cookie recipe.” This habit both prevented him from being the cause of sensitive data

being exposed and it served as a reminder that everyone should be aware of this potential situation.

COPPA

The Children's Online Privacy Protection Act (COPPA) has been law in the United States since 1998. The intent of the law is to protect the privacy and the personal information of children; thus, it requires the publishers of web sites that collect user information to have parental consent for those under 13 years of age. This is the law that has motivated social media companies to restrict children from accessing their platforms. Of course, it is very difficult to enforce age restrictions, but the terms of service and privacy statements of companies that maintain web platforms, especially those that facilitate interaction among users, do reflect the requirements of the law. Because of COPPA, most schools, especially those enrolling students younger than 13, have procedures for identifying the online platforms that have been vetted for use by teachers with students. A teacher may find that they are not allowed to have students logging on to and using an interesting new tool until the terms of service have been reviewed and school leaders conclude it is reasonable to allow access and the publishers of the site align with local policy and procedure.

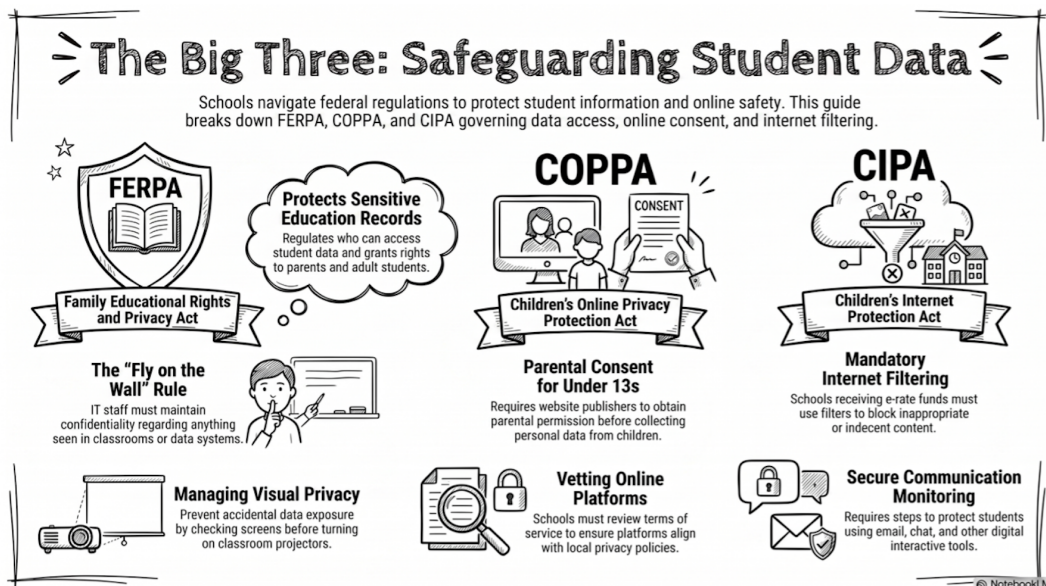
CIPA

In 2000, the United States federal government passed the Children's Internet Protection Act (CIPA) which is intended to protect children from indecent information on the Internet, it is also intended to prevent personal information about students from being available online. Specifically, CIPA requires schools that receive E-rate funds to install and maintain filters to restrict access to inappropriate content, and it requires steps to be taken to protect youngsters when using email, chat, and similar tools. CIPA does allow the filter to be disabled when only adults are using the network, but that is

rarely done as children are hardly ever absent from school when adults are there.

School IT professionals can be expected to participate in the planning undertaken to ensure the school complies with CIPA. They will review policy and procedures to ensure Internet filters are configured and operational, email and chat are available only to those users for whom it is permitted under local policy, to manage firewalls, and to otherwise protect children who are using the school's IT systems. The planning takes on special importance when systems are being updated, or older devices are being replaced. In addition, IT professionals are expected to monitor systems installed to comply with CIPA are functioning, and to define steps to take if they fail.

Figure 7
Laws Regarding Privacy and Security in the United States



Advertisement-Driven Sites

Another overlooked aspect of IT use in schools is students' exposure to advertisements. Many sources of online information used in schools, including mainstream media and journalism sites, the sites of professional organizations and edited periodicals, and especially social media sites (like YouTube) are funded by advertisements. When students access these sites, they are also exposed to the advertisements.

Some educators, students, parents, and others object to this exposure for several reasons. First, this can be perceived to be the commercialization of students (Internet Safety Labs, 2022). Students are required to attend school, and they have little choice over the lessons and materials they use. By directing them to information sources that are advertisement-rich, teachers may be exploiting students. Second, some of the products may be unsuitable for children, especially in school. Even if the products are not unsuitable, they may lead to distractions or they may contribute to inappropriate situations.

IT professionals may be asked to minimize students' access to advertisements when at school, this may include installing and configuring software or web browser extensions that block advertisements. In addition, IT professionals may be asked to support faculty as they embed media in virtual classrooms or otherwise minimize exposure to advertisements.

Other Privacy and Security

Regardless of the nature of the organization in which they work, all IT professionals are very familiar with the importance of network and data security; this is a lesson taught in preparation programs and all organizations implement data security practices. IT professionals working in schools should also promote data security, but they must be sure their actions align with the decision-making hierarchies in schools and accepted policy and procedure.

Schools are places where IT professionals and others are very likely to find passwords on sticky notes attached to computers (while this is becoming

less common, it is still more common than it should be). In some schools where I have worked, technicians and other IT professionals were encouraged to remove those sticky notes, but that was done only with the knowledge and support of the school administrators. Another common practice is for teachers to keep list of their students' usernames and password. Ostensibly, this is done to reduce troubleshooting when passwords are forgotten, but there are other strategies whereby passwords can be recoverable without the potential of them being discovered and used for nefarious purposes.

I have reasoned (Ackerman, 2021) that educators should not be posting images or videos online in which students are recognized, and there does seem to be a good deal of support for avoiding this practice. Others reject my claim citing waivers parents and guardians sign allowing such posting. I argue such waivers must be done with informed consent, and because we cannot tell what might happen to an image shared online, we cannot fully inform those who grant the waiver. (I also find the practice of allowing an adult to decide what can happen to a child's images reprehensible.) Regardless of the existence or appropriateness of any waiver, any educators who share a picture which leads to any harm coming to a student to be an indefensible position.

Acceptable Use Policies

The leaders of all organizations take steps to protect themselves and the organization from liabilities and damage resulting from the inappropriate use of IT systems. At the highest levels, the organization's governing body (school board are generally responsible for adopting policy) will adopt policies to protect the organization by ensuring they comply with relevant laws and regulations, and to minimize threats to the IT systems which represent a significant expense. As long as policies are lawful, and policies are usually written with significant input from the governing body's legal counsel, then policy defines what IT users can do using its IT systems and violation of policies can lead to termination of employees.

While policy is the ultimate rules that must be followed, users of IT typically follow procedures which are more easily understood, and which have been defined to facilitate management of the systems for everyday use by teachers, students, and others. If it is discovered that IT procedures violate policy, they will be overturned. In schools where collaborative IT planning is observed, new procedures that meet the needs of the IT professionals, but that align with policy will be defined with the input of multiple stakeholders, including school administrators, which reduces the likelihood that procedures will be overturned. Revising policy takes a significant amount of time and policy makers typically revise IT (and other policies) on a regular basis (usually with years between revisions).

While the acceptable use policies adopted by school boards are the ultimate policy that must be followed, those can be written in language that is difficult for laypeople to understand. This is especially true regarding children, who we know comprise the majority of school IT users. In response, IT professionals and educators will collaborate to create “acceptable use policy” documents that are written in language that is appropriate for the students.

Having students and adults sign AUP’s is a largely symbolic activity in schools. The signature does indicate students, parents, educators, and others have been made aware of the policy. Whether one has signed an AUP or not, they are obligated to follow policy and failure to follow the policy can result in school administrators taking actions to ensure policy is followed. Because it is symbolic, it does not mean that AUP’s are meaningless. These can present a valuable opportunity for teaching students about cybersecurity, cyberbullying, privacy, and other situations in which IT may be misused, and lessons focused on the school’s AUP are often included in the curriculum in part to address the International Society for Technology in Education’s standards related to digital citizenship.

End-User Devices

IT People Touch

Computers and digital data would be easy to manage if it were not for the fact that people use them to access data and complete tasks. The most obvious role of the IT department in any school is to support end-user devices—the ones used by students, faculty, and staff to interact with data. In many organizations, the enterprise devices are standard; everyone gets a similar device. In schools, we keep systems in place longer than in many other organizations, and there tend to be more specialized devices installed, as well as more devices which are used for different purposes during a school day. This chapter explores the devices held by students and teachers and other users in schools.

When desktop computers began arriving in schools in the 1970s and 1980s, they were stand-alone devices. Applications were saved on floppy disks stored in boxes next to the computer (which also looked like a box). Users selected the application they needed, placed the disks into the drive and booted the computer. As the machine powered on, the application was loaded from the spinning diskette. We opened, edited, and saved data on files inserted into the second drive on the computer, and all commands were given with the keyboard; there was no graphical user interface. When we needed to use another application, we powered the computer off, inserted new application disks, then powered the computer back on. We did one thing at a time on our computers and data created in one application could not be copied and pasted into another.

In the mid-1990s, networking protocols were added to operating systems, and external modems were replaced with network interface cards in most computers. By then, mechanical hard drives, mice and other pointing devices, color displays, and graphical user interfaces were installed on desktop

computers finding their way into schools. Today, network connections are vital to operating system functionality, software licensing, and most other aspects of managing our computing devices. Applications are installed via network connections or provided as web applications users access with web browsers and many sources of data are accessed via internet protocols.

In the 1980s, when my students could be accurately described as “computer users,” I now say they are “system users” (Selwyn, 2016); any computing task will find them creating and editing data on an end user device, but its function depends on network connections to servers that provide both applications and data. In this chapter, we focus on the devices found on the desks and laps of school users, but they compute as much with local area resources and internet resources as we do with these devices.

One word of caution. Just as schools are places with local curriculum and instruction systems, schools tend to be very localized technology environments. Budgetary limits, the expertise of local personnel, legacy systems that are still in place, and the leadership structure of schools influence the infrastructure found in schools. Readers who are familiar with the technology in local schools will find differences between what I describe here and what is installed locally. Further, those with experience as IT professionals may find my descriptions to be too broad. Remember, my goal is to help those who care about school IT so they will not be surprised at what they find, and to help school leaders to understand the technology in their schools.

The first computers connected to a local area network installed in a school were Macintosh machines and were installed by a teacher-turned-technology professional. There was a dispute between the school leaders and the individual who had installed them, and as a result he refused to provide the passwords necessary to manage them. The superintendent of schools had the machines removed and replaced with PCs with Windows installed. Decades later, the school continued to deny any requests for Macintosh computers.

When I was a student, in the 1970s and 1980s, we had basically no computers for students to use. Today, in many schools every student and

teacher has a device. This transition happened over time, with different phases commonly noted in many schools. Computers started out in classrooms (often in “one-computer classrooms”), then moved into computer “labs,” then they returned to classrooms, with some specialized computer rooms still available.

Table 8
Models of School IT

Classroom Model	Number of Devices	Location	Common Teaching
One-computer	1 or 2	In classroom	• Teacher-led simulations • Converting paper files to digital
Computer “Lab”	25 was a typical number	In special rooms	• Touch-typing or similar skill-based software • All students working on projects • Students conducting research
One-to-One	1 device per student	In classrooms	All the above, plus accessing shared documents or a learning management system

Often desktop computers were housed in classrooms. For example, a physics-teaching colleague and I rewrote much of the laboratory curriculum for our courses one summer to allow sensors to record data directly into computer

files. Our lab had three computers for this purpose, and it represented the most computers in any space at the school. We had not been using that curriculum for a year, when the first computer room was ordered by the school and students started going to rooms filled with computers for special projects or for courses. Today, one-to-one initiatives are very common, and computers have returned to classrooms. While much of my career in education has been spent trying to get devices in the hands of students, today we are recognizing the distraction that can be caused by devices capable of multitasking (Zheng et al., 2016).

The Capacity of Devices

Teaching and learning require students to 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. Those tasks necessitate managing small amounts of data, so the necessary processing power is minimal, and the output is simple enough that a low-resolution display is sufficient, and minimal network connection allows the work to be completed with minimal latency on most networks. Other information tasks central to the curriculum require greater computing capacity and bandwidth; creating video and editing photographs are examples of such tasks. 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 rate at which information is processed*—Processing speed is captured in its clock cycle which is measured in giga-hertz (GHz). It used to be a good proxy for the capacity of the computer to complete tasks, but today, factors such as the number of cores running in parallel and the availability of cache improve the capacity of the central processing unit to complete operations.
- *The amount of random access memory (RAM) available to the processor*—RAM has always been important in determining the capacity of a computer. It has been relatively inexpensive and easy to install, 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 Google Workspace 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. Furthermore, excessive applications or extensions in the operating system or in web browsers can also interfere with efficiency.
- *The sophistication of the applications*—Applications are the software used to manage and create information; many applications 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 to 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 determinant of sufficiency. For many users, the capacity of computing devices is less about information processing and more about enabling interaction. 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).

Full Operating System Devices

Of the devices marketed to schools, those with the greatest computing capacity will arrive with a full operating system installed on the hard drive. Full operating systems include Windows, the Macintosh OS, and Linux (an 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 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 more easily through rough use compared to desktop models. Decreasing performance of batteries and other components limits 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 the 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. Students can collaborate writing scripts using Chromebooks and Google Workspace applications. When they record the performances, they will require cameras that capture the footage on the devices, or perhaps a drive connected to a computer with that full operating system with software to buffer and record the raw footage without interruption. It is likely the performance would be recorded on multiple cameras 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.

Tablets

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). There are versions of Linux that are designed for mobile devices, but their use is marginal, especially in schools. 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. The single-use nature of users on tablets refers to the individual users accessing the devices. On those tablets that use the ChromeOS, identity and access management of those users is controlled by the Google Workspace accounts to which they connect. It is not unusual for 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 (Aspiranti et al., 2020; Al-Naim, 2026). 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 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 they 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.

ChromeOS 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 Chromebooks, which are 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 application 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 Google Workspace account; all other productivity tools that are used on the Chromebook must be available via a web service.

Table 9
Comparing Characteristics of Different Types of Operating Systems

Feature / Dimension	Full Operating Systems	Mobile Operating Systems	Google ChromeOS
Estimated Unit Cost	High (~\$1,000/ unit)	Moderate (~\$400/ unit)	Low (~\$300/ unit)
Hardware Longevity	High	Moderate	Moderate
Software Capacity	Maximum	Moderate	Web-based (
User Profile Structure	Multi-user support with local/network profiles	Primarily single-user profile per physical device	Multi-user via Google Workspace cloud login
Management Overhead	High	Moderate to High	Low (
Ideal K–12 Use Case	Digital arts, multi-track video editing, computer science, CAD	Primary grades, special education, interactive haptic learning	General classroom 1:1 fleets, web research, document editing

Managing a fleet of Chromebooks in a school requires an IT professional to log on to the online administrative dashboard provided by Google and selecting from the options available from Google or from third-party publishers; Google has a history of providing both Google Workspace 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 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 the devices were to be deployed. The actual cost of deployed functional Internet-only devices may depend on upgrading network capacity.

Applications

Computers are useful based on the software that is installed. We use productivity suites (such as Microsoft Office and Google Workspace applications) to create files and understand and analyze data. We use other software to edit images, video, and audio, and other software to attend virtual meetings.

Just as there are different types of operating systems, there are different types of applications, and these have different capacities to do what they do. Depending on the needs of the students, different types of applications may be needed to satisfy their classroom needs. An excellent example of the types of applications and their capacity is video editing software.

The least sophisticated type of video editing software is cloud-based. These web applications allow users to upload short clips and apply clips sections, rearrange contents, add transitions, add text overlays, record additional audio, and otherwise edit the video. These are generally useful for basic video editing as they are limited by the bandwidth needs, especially for high resolution projects, a lack of features, and concerns over privacy. While these are largely available to students and teachers, they are typically used for

students to complete projects or for teachers to record brief instructional videos.

A more sophisticated type of video editing software is installed on computers, but these applications have limited capacity and tools compared to professional level software. These are more sophisticated than cloud-based systems and tend to have more features and are not limited by the bandwidth needs of transferring data to and from the internet. Most software of this type supports single-track video editing. These are also widely used in schools, typically by older students and by teachers.

A third type of video editing software extends and enhances the tools and allows users to import and edit multiple tracks. An example of a school project that necessitates this type of software is editing a performance, such as a play that was recorded from multiple cameras. A clapperboard is used to synchronize the recordings, and the audio and video from that event is used to ensure that the video and audio matches when the editors switch views. This type of software is much less widely used in schools. There is another class of video editing software rarely used in schools as it is intended for professional video editing.

Negotiating End User Purchases

When making decisions about which devices to purchase, school and technology leaders often find they must negotiate between several characteristics of the technology to ensure it meets the budget limitations while meeting the needs of the teachers and students. While the final decision may result from several rounds of discussions, most begin with a budget limit, which is what we would expect when the implementation is to be reasonable. The other factors that affect the decisions are the number of devices needed and the capacity of the device to manage the data and the applications necessary for the curriculum and instructional needs to be met by the devices.

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- *It is not essential that all students and users have access to the same devices all the time.* A computer that is sufficient for one use may be underutilized for other instructional purposes, so efficacious educational technology results from the students having sufficient devices for the needs. This may require a limited number of devices that have more capacity than the devices assigned under that school's one-to-one initiative and using these devices may require a system for scheduling.
- *The capacity of the devices* is also a factor to consider. More expensive devices do provide more capacity. But if budgets prevent teachers and students from accessing the software they need, then we must recognize the technology has limited effectiveness.
- One advantage of Chromebooks is *the ease of device management*. The operating system is less sophisticated than a full operating system, so updating it is much easier. User and identity management is generally less sophisticated compared using Google Workspace than a traditional network operating system.

There are no heuristics that can be used to determine what are 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 their day in a typical high school, they may encounter a variety of information tasks that each require a different type of device.

Classroom Tools

In addition to the devices with display and keyboards for end users, many other types of devices are available and used in schools. The fleet of end-

user devices is likely to include devices for large groups of students as well as some for smaller groups of students.

Projectors

Projectors connect to computer displays to allow a classroom or theatre to view the contents. In recent years, a range of consumer grade projectors that are very inexpensive (less than \$100.00 US per unit). Projectors designed for classroom use cost several hundred dollars, and those for auditoriums or theatres cost thousands of dollars.

The controls available within the software installed on projectors allow technicians to configure details of the displays, including flipping the displays to allow for ceiling mounted installations. Projectors are designed to display content in specific resolutions; when projectors have been left in service for a number of years, there can be conflicts between the displays of the computer and the displays connected to it and the resolution of the projectors.

Interactive Whiteboards

Another common piece of hardware one encounters in schools are interactive whiteboards. When these whiteboards are connected to computers, they function as an input device. Teachers and students can control the computer to which it is connected by tapping the board, and they can draw on images, markup text documents or slide shows, or write or draw in other applications by interacting with the whiteboard.

Among both teachers and IT professionals, interactive whiteboards have both strong advocates and detractors. For IT professionals, the devices are notoriously difficult to troubleshoot and repair and they are unreliable compared to most other technology devices. A colleague summarizes his perceptions of interactive whiteboards with his oft-repeated statement, “if any device is going to fail, it is one of those.” They also tend to have few user-serviceable parts, so repairs often necessitate ordering replacement boards or components from the manufacturer. These devices are also very expensive

compared to other computing infrastructure, so they tend to stay in service for a long time, in many cases whiteboards are used past the “end of life” date of the manufacturer, so catastrophic failures are not uncommon, and they can represent an unplanned significant IT expense and a disruption if the teacher actually uses the interactive elements of the board.

Many educators object to interactive whiteboards because they are placed in the front of classrooms and displace regular whiteboards. If the interactive whiteboard is not perceived to be an improvement compared to a regular whiteboard, then it is less likely to be used and will be perceived as a barrier to effective teaching. Others find interactive whiteboards to encourage teachers to lecture at a time when the learning sciences are finding other instructional methods are more effective than lecture.

Touch Displays

Interactive whiteboards are increasingly being replaced with touch displays. In many cases, these displays are as large as an interactive whiteboard in a classroom. These devices allow users to interact with the display in the same way that any input devices do. Teachers, for example, can markup slide shows, web sites, or word processing documents.

Most touch displays arrive with an onboard computer that typically runs a version of Android, which operates that device when it is not connected to a desktop or laptop computer. They also contain universal serial bus and video ports to allow them to be connected to and interact with computers, so the teacher can access their files on a familiar interface. There are some models of touch displays that feature on-board PCs as well so users can access a full operating system from the devices itself.

In general, these devices have more luminosity and greater resolution than projectors, so they are popular for classrooms. If the classroom is large, it is often necessary to install additional displays to mirror what is happening on the classroom computer for students in the back of the room.

Special Use Computers and Devices

In addition to the fleets of computers maintained for populations such as students and teachers, schools are places where special purpose computers and peripherals are found. In makerspaces, science laboratories, studios, workshops, and other special teaching spaces, there are computing devices necessary for specialized educational activities. Examples include:

- *Raspberry Pi*—These small, affordable single-board computers are designed for education, experimentation, and embedded projects. They run Linux-based operating systems and enable students and makers to learn programming, electronics, and computing through hands-on exploration.
- *Arduinos*—These microcontroller boards are inexpensive and use open-source software, so they are used in makerspaces and similar spaces in which students design and program digital devices.
- *Robots*—There are several organizations that sponsor robotics competitions for students, and these are also popular devices in makerspaces and in science, technology, engineering, and mathematics (STEM) classrooms. IT professionals encounter a wide range of robots in schools as well. Elementary students may use toy-like robots while students in technical schools may use programmed logic control (PLC) devices for mechatronics applications in manufacturing classrooms.
- *Printers*—Much of the printing that happens in schools is high-volume and low-quality. Today, most print jobs in schools are directed to network-connected photocopiers that also serve as scanners. Many schools also provide limited access to color printers for specific purposes. Teachers may find it necessary to print some instructional materials in color, and digital arts classrooms may have printers specialized for printing photographs installed.

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- *3-D printers*—Students in makerspaces and STEM classrooms are also likely to be gaining experience with additive manufacturing.
- *Science apparatus and interfaces*—Teachers in science laboratories have adopted many digital data collection tools in recent decades. Interfacing devices allow various probes to be connected to software so that (for example) temperature can be collected and graphed in real time. In addition, familiar devices from the analog laboratory, such as microscopes, are now digital. Combined with a high-resolution display, these microscopes afford more specific instruction by teachers than traditional microscopes and students can capture images to use for more accurate analysis compared to the traditional methods.
- *Music composition stations*—Music teachers and students often make use of hardware as they record and create compositions.
- *Assistive technologies*—In order to access their education, some students need very specific hardware or software. Decisions about what assistive technologies are necessary are made on a case-by-case basis and a team of IT professionals, outside consultants, and special educators collaborate to identify, select, and deploy the necessary assistive technologies. In most cases, assistive technologies are for the exclusive use of individual students. Those individual students need the device all the time and it is unlikely other students will need it.

Total Cost of Ownership

When we make decisions about the technology to obtain in an organization, we must recognize there exists a total cost of ownership (TCO) which reflects the sum of all the costs associated with using any piece of technology or technology system (Consortium for School Networking, 2003). These costs can include infrastructure and utilities, costs related to security and maintenance, and operational costs.

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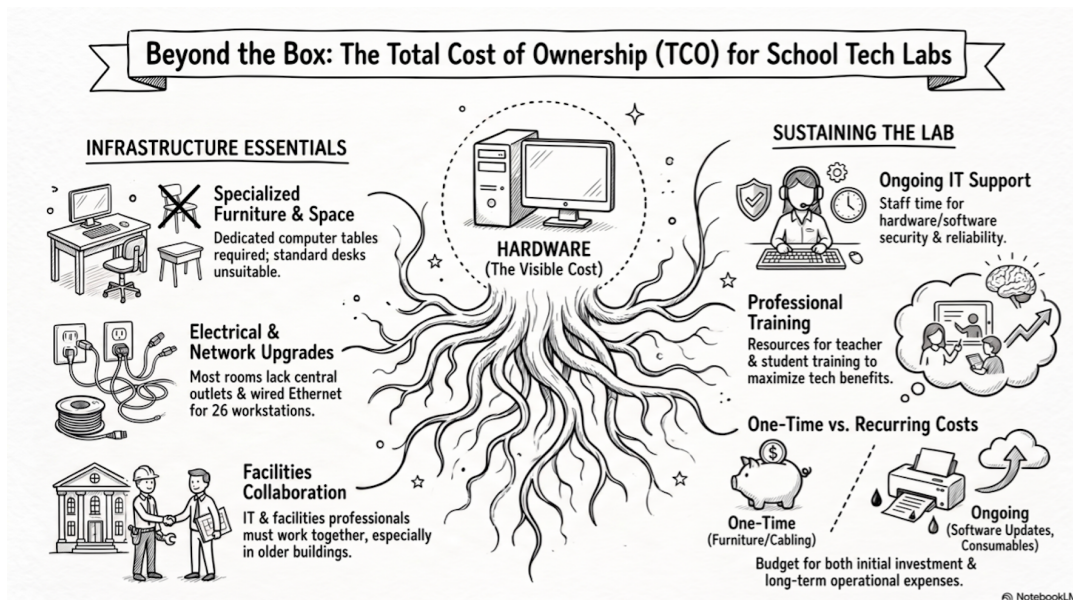
Consider the costs associated with installing a 25-station multimedia computer room in a school. In this case, I will assume there is a classroom that is configured as one would expect for the standard model of education: desks in rows with a teaching station that has a projector and screen in the front of the room. We plan to install 26 identical workstations, 25 for students and one for teaching. Because of the nature of the software that will be used, the computers must have a full operating system. The following will contribute to the TCO:

- *Furniture*—It is likely the student desks in most classrooms would not be appropriate for placing computers for student use, so new tables are likely to be necessary.
- *Network infrastructure*—Connecting desktop computers to the local area network and the internet is typically done via wired Ethernet cables. Installing and configuring the switches necessary to manage these devices will affect the TCO.
- *Electrical infrastructure*—Most classrooms do not have sufficient electrical outlets for 26 computers, and if the outlets do exist, they are unlikely to be located in the center of the classroom where most of the computers in this room would be located, so the TCO would require professionals with the proper credentials to install the necessary outlets.
- *Software*—Depending on the exact needs of the curriculum, the operating system and applications needs for the courses to be taught in this multimedia room must be obtained.
- *Peripherals*—Also affecting the TCO of this multimedia room would be the cost of printers, cameras, and similar devices to aid in the production and distribution of projects students create there.
- *IT support*—Installing and managing the hardware and software to ensure it is secure and reliable in this room would cost time from the IT staff. While adding a single room with 26 full operating systems and

multimedia applications would probably not necessitate a full-time person to manage, it would consume some of their time.

- **Training**—Depending on the nature of the software and the skills and knowledge of the people to be using it, resources may be necessary to ensure it is used properly, so the students benefit from the full capacity of the computers and software.

Figure 8
TCO of School Technology



The list of items that comprise the TCO for any IT projects is going to include some one-time expenses, for example furniture and networking infrastructure that are likely to extend for much of the life of the IT, and on-going expenses. Deploying software updates and performing other maintenance and consumables such as ink or toner for printers are examples of on-going TCO expenses. Yet other TCO expenses can vary. For example, once teachers become knowledgeable about the software and understand how best

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to use it, the training costs may disappear but return if new teachers begin using the space.

IT professionals who collaborate to create efficacious educational technology understand the costs associated with TCO and work with those other professionals to ensure they can manage IT projects with their own projects. In my experience, one of the most important relationships any IT professional can have when working in a school is with the facilities professionals. This is especially true when you manage IT in old buildings that were constructed decades before IT was being installed.

Network Configuration

IT Users Don't Touch

Within a school building, there exists a very sophisticated digital infrastructure that most people never see. If they do see it, it is probably through an open door that was quickly closed behind the IT professional who opened it and who locked it immediately. The local area network infrastructure connects computers (and the people sitting at them) to other resources on the local network and the Internet. While every end user device depends on these connections, the devices are kept out of reach of those who do not need it.

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. 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 for their own purposes). 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, so prudent IT professionals secure the wiring closet to ensure only those who understand what each part does can access spaces where networking device are stored. While IT folks may want to prevent school administrators from accessing it, it is essential that school administrators understand the protocols for accessing it, the individuals

who can access it, and the conditions under which they should know what is being done to it.

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 and management tasks and limitations), so they can make decisions about what is a reasonable implementation.

Three Classes of Networks

Ethernet is the foundational network technology used in schools and virtually every other organization. Historically, Ethernet was developed at Xerox PARC in the early 1970s by Robert Metcalfe and colleagues as a way to link computers within a local area. Its simplicity, reliability, and ability to evolve with faster speeds made it the universal standard for wired networking. Over the decades, Ethernet displaced competing technologies and became the backbone of nearly all modern data networks—from classroom labs to global enterprises—thanks to its open standards and scalability.

When computers and devices connect through Ethernet, they rely on the same protocols and hardware regardless of how many nodes are on the network. The equipment that forms these networks is designed to meet the needs of three distinct classes of networks; each scaled for different environments and performance requirements.

- *Consumer class*—Commonly installed in homes, equipment in this class is used to connect a few dozen devices. These are often configured for “plug-and-play” connections of computers, tablets and smartphones, and a variety of Internet of Things (IoT) devices. While consumer devices

may offer a secondary “guest” network, they lack the ability to segment traffic into multiple, isolated virtual networks (VLANs) which is necessary for many of the data needs we find in schools.

- *Business class*—Business class networks are designed to connect 200-300 devices. These networks require configuration rather than relying on “plug-and-play” configuration found in consumer networks. They also allow for more sophisticated security options to be configured.
- *Enterprise class*—For even larger networks, those connecting several hundreds or thousands of devices, enterprise class networks must be configured. These allow for very sophisticated configuration and management, and they allow similarly sophisticated security.

One of the challenges for IT professionals is the ease of configuring consumer devices. Many educators who have installed a consumer network may conflate the plug-and-play configuration with the configuration of enterprise networks. Enterprise networks require professional planning and installation and managing them requires a full-time staff to manage the network. The leap from consumer to enterprise isn't just about speed; it's about the fundamental shift in how the network is managed and secured.

Table 10
Review of the Classes of Networks

Feature	Consumer	Business	Enterprise
Management	Individual / App-based	Centralized Controller	Cloud or On-Prem Platform
Security	Basic (WPA2/3)	Radius / WPA-Enterprise	Advanced Threat Detection
Scale	Single Home	Small Office	Campus-wide
Longevity	2–3 Years	3–5 Years	5–7+ Years

Local Area Networks and the Internet

Local area networks (LAN) entered most educators' experience in the mid-1990s when the first servers to be regularly accessed by teachers and students arrived in schools. Early uses of LANs 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. The first LANs in many schools were building-based, but it did not take long for schools across districts to be connected via internet protocols to extend LANs across districts. In many school districts, different campuses were connected to create a unified network environment, allowing resources to be shared across campuses as easily as if they were in the same building.

Increasingly, services that were provided by LAN servers, such as file sharing and web applications (such as library card catalogs), have been abandoned as cloud-based systems became available. While that may change some aspects of IT professionals' work, it does not reduce the importance of the local area network in providing essential network services for school users. In fact, as the cloud becomes used for teaching and learning, data management, and business operations, the LAN becomes more important as it provides reliable, robust, and secure connections to cloud-based resources.

Each network, regardless of its class, sends traffic from devices on it to the gateway and through it to the internet; if the gateway is dysfunctional, users can still use the LAN resource, but if their connection to the LAN fails, they will only be able to use applications and data stored on drives connected to their computer. As schools have migrated to the cloud for systems that support teaching and learning, the LAN can become a "single point of failure." A robust local network is the prerequisite for accessing the digital resources that modern education requires.

Understanding Bandwidth

“The network is slow” is a common complaint for all users of computer networks at home, in offices, or in schools. We often use the term latency to describe slow computer or network operations. Sometimes latency problems can be traced to the end user device, and restarting it resolves the problem. At other times, technicians may update the configuration on a specific device to minimize latency. When using a consumer-grade network, restarting the gateway often resolves latency issues.

When managing enterprise networks, restarting the gateway is usually not an option; we cannot afford such a disruption for the hundreds or thousands of users connected to the local area network. System administrators can adjust the configuration of network devices to address latency on local area networks. They look for bad cables, bottlenecks, overloaded switches, or other misconfigurations to ensure maximum bandwidth for all users.

Bandwidth is a measure of the rate at which information can be transferred over a network in a given time. 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. When we design networks, we take steps to ensure redundancy so that our networks are likely to avoid a single point of failure and we identify potential bottlenecks that can lead to increased congestion and cause increased latency.

Broadband is the term used to describe “large amounts of bandwidth,” but it is a relative term. In 2024, the Federal Communication Commission (FCC) in the United States of America increased the minimum data rate for connections to be considered broadband to 100 megabits per second (Mbps) for download speeds and 25 Mbps for upload speeds (FCC, 2024). In the same document, the FCC recommended schools maintain 1 gigabit per second (Gbps) upload and 500 Mbps for download speed for each 1000 students. These numbers provide benchmarks for school IT leaders when completing Erate

applications (the US program providing discounts for telecommunications and internet access) and for technology planning purposes.

All network devices (including the network adapters installed in computers) have a data rating, which reflects the maximum amount of information that can pass through a 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 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, and 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. Ethernet breaks a file that is to be transported over a network into packets. Packets are sent individually, then reconstructed on the client computer. When packet loss occurs, users

experience latency, and system administrators will troubleshoot the problem. 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.

The bandwidth available to users 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. This is one reason that limitations on network use may be instituted during testing periods in a school. If there are 200 students taking a high-stakes test that requires sufficient bandwidth to the providers of the test, then steps may be taken to minimize other network uses at that time.

If the maximum bandwidth available from the local ISP is inadequate for the demands of a school, 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 the extra demands. In recent years, many schools have converted to voice over Internet protocol (VOIP) telephone services. Because of the importance of 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.

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 because of a computer that was infected with malware and sending vast amounts of data. However, 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.

Fundamentals of Networking

Logically, 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). Also, fundamental network administration is knowing who users are and what they have permission to do. Whereas the logic of networks is elegant, the management of them is complex. System administrators interact with many software interfaces (or type many commands in terminals) to ensure secure and reliable access to all users. Fortunately, there are accepted procedures for making the necessary configurations.

Managing IT tends to be a tame problem. There are accepted steps for isolating and resolving malfunctioning technology. Once the problem is

isolated, we can follow known steps for resolving it. If we do not immediately know the resolution, we access materials or other people to give us direction.

Cables and Access Points

So that networks can send and receive data as expected, there must be some way to get the bits from clients to server and from servers to clients. In the Ethernet networks that dominate school networks, the bits travel through twisted pair cables or through radio waves.

Table 11

Types of Twisted Pair Cables Used for Ethernet

Cable Type	Max Speed	Max Distance at Max Speed	Bandwidth	Use Case in Schools
Cat-5e	1 Gbps	100 m	100 MHz	Legacy networks, VoIP, basic classrooms
Cat-6	10 Gbps	100 m (1 G) / ~55 m (10 G)	250 MHz	Modern classrooms, AP uplinks, office drops
Cat-6A	10 Gbps	100 m	500 MHz	High-density Wi-Fi, future-proofing, MDF/IDF runs
Cat-7	10 Gbps	100 m	600 MHz	Specialized environments; rarely used in K–12
Cat-8	25–40 Gbps	30 m	2000 MHz	Data centers; not used for building wiring

Desktop computers typically connect through twisted pair cables that connect to RJ-45 ports in the computer which connect to the network interface card (NIC). Twisted pair cables contain 4 pairs of copper wires that are twisted to reduce electromagnetic interference along with insulation and it is wrapped in a PVC coating. However, RJ-45 connectors and ports are not universal across all networking hardware. Also, the nature of the twisted pair cables has changed as the Ethernet standards have changed. As we near the end of the third decade of the 21st century, cat-6 cables and RJ-45 are typically found in schools. Cat-6 cables can be up to 100 meters long for a 1 Gbps protocol; the signal becomes attenuated (or weakened) after 100 meters. In cat-7 and cat-8 cables, there is also shielding to further minimize interference. Ethernet conforms to Institute of Electrical and Electronics Engineers (IEEE) standard 802.3 (IEEE Standards Association, 2018; IEEE Standards Association, 2021).

Laptop computers, tablets, Chromebooks, smart phones, and even desktop computers that have wireless NICs installed all connect to Ethernet networks via radio waves. Access points are network devices that connect to Ethernet via a twisted pair cable, then send and receive signals to devices in its footprint. Wireless conforms to IEEE 802.11 standards, which have evolved since it became available.

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. Many access point devices receive power over Ethernet (PoE), which means a single cable is all that is needed to connect it. To connect to the wireless signal coming from the access point, a computer or mobile device must have a wireless adapter installed and configured to connect to it and be within range of it.

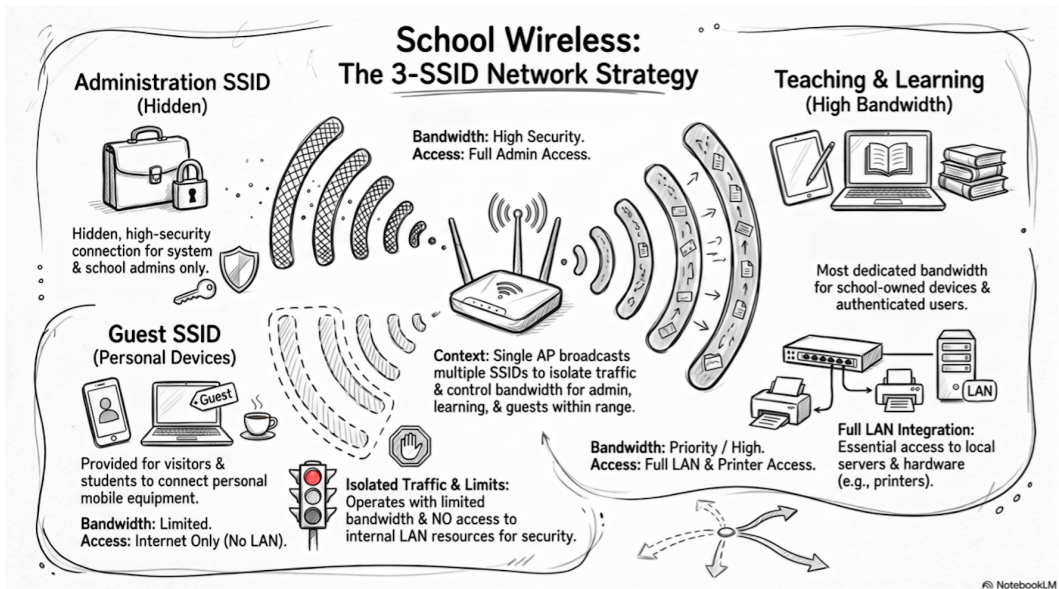
Table 12
Wireless Standards

Standard	Release Year	Max Speed	Frequency Bands	Key Features / Notes
802.11b	1999	11 Mbps	2.4 GHz	First widely adopted Wi-Fi; slow; high interference.
802.11a	1999	54 Mbps	5 GHz	Faster than 11b; shorter range; less interference.
802.11g	2003	54 Mbps	2.4 GHz	Backward-compatible with 11b; common in early 2000s.
802.11n (Wi-Fi 4)	2009	600 Mbps	2.4 & 5 GHz	Introduced MIMO; major speed and range improvements.
802.11ac (Wi-Fi 5)	2013	3.5 Gbps	5 GHz	Wave 2 added MU-MIMO; dominant in schools for years.
802.11ax (Wi-Fi 6)	2019	9.6 Gbps	2.4 & 5 GHz	OFDMA, better performance in dense classrooms.
802.11ax (Wi-Fi 6E)	2021	9.6 Gbps	2.4, 5 & 6 GHz	Adds 6 GHz band; low interference; ideal for schools.
802.11be (Wi-Fi 7)	2024–2025	30+ Gbps	2.4, 5 & 6 GHz	

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 SSIDs are available, and the user can select the SSID to which they want 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 SSIDs 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.

Figure 9
A Typical SSID Strategy for A School

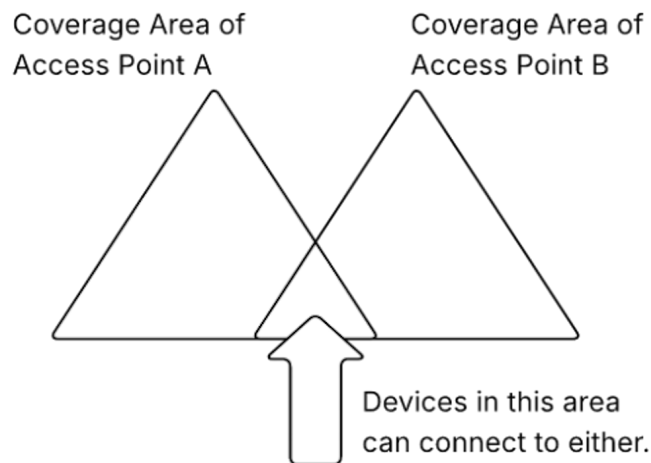


An access point can be configured to offer SSIDs to devices within its range (typically a few tens of meters depending on building materials and power rating), and the SSIDs can provide both isolate traffic and limit bandwidth for users connected to it. A common configuration is to make three SSIDs available 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 and most of the bandwidth is dedicated to this SSID. 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 it does not provide access to LAN resources.

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 signals from two different access points in a classroom, 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.

Figure 10
Spaces Covered by Two Access Points



The term “wireless” can also be used to describe the cellular networks to which smartphones and tablets can connect. These networks are independent of the Ethernet wireless networks in schools. They bypass filters, firewalls, and other tools to secure school networks.

Addressing

When we connect computers, tablets, Chromebooks, printers, access points, switches, or any other devices to the local area network via Ethernet, it works using the internet protocols that are built into the operating systems on computers and network devices. Internet protocols are the rules and standards that allow computers and devices to communicate reliably across networks, from local school LANs to the global internet. They define how data is packaged, addressed, transmitted, routed, and received, ensuring that every device—no matter the manufacturer—can exchange information successfully.

When communicating using these networks, data sent and received is broken into packets and frames. Packets and frames are created using different protocols in the layers of network software. Packets move information across the internet and frames move data over Ethernet. Each contains information about the source address, the destination address, the payload, and error checking fields. Once it is received by the client, it is reassembled and checked for errors before being sent to the application where it is displayed. Sometimes when we experience latency when using networks, it is because the buffer is empty and it is awaiting more data from the server.

All communication relies on the network 'knowing' which devices are which. This is accomplished using two distinct types of addresses assigned to every network interface: a Media Access Control (MAC) address for local delivery and an Internet Protocol (IP) address for logical routing. Protocols then work behind the scenes to link these addresses together, ensuring that data sent to a specific IP reaches the correct physical hardware.

Media Access Control

The Media Access Control (MAC) address is the physical address of a network interface card (NIC); it is programmed into the hardware when manufactured. While this address is permanently assigned, identifying a device with precision, modern software can sometimes mask it for privacy. Network sniffers, for example, identify the MAC address of every device sending or receiving frames.

To find the MAC address on a Windows computer, one typically enters “ipconfig /all” in the command prompt. It will be listed as the physical address. It is a 48-bit identifier expressed as six pairs of hexadecimal digits (e.g., 00:1A:2B:3C:4D:5E).

MAC addresses are used by the Local Area Network (LAN) to ensure data reaches the correct destination. Switches maintain a MAC address table to associate specific addresses with physical ports, ensuring that data is only sent to the intended recipient rather than being broadcast to the entire network.

Internet Protocol (IP) Addressing

While a MAC address identifies a specific piece of hardware, the Internet Protocol (IP) address serves as a logical identifier that indicates where a device is located on a global or local network. If a MAC address is like the locations of a classroom in a school—each unique and tied to the specific space—then an IP address is like the school’s mailing address. It provides the necessary routing information so that data can travel across different interconnected networks to find the correct destination.

IP addresses are assigned to devices by network administrators or automatically via software protocols like DHCP (Dynamic Host Configuration Protocol). Without DHCP, a network administrator would have to manually type a unique IP address into every single computer, tablet, and printer in a school—a task that would be nearly impossible in large schools. Instead, when a device connects to the LAN, it broadcasts a request to a DHCP server (often

built into the switch). The DHCP server then assigns a "lease" of an available IP address to the device for a specific period.

Because they are logical rather than physical, Internet Protocol (IP) addresses can change. For example, your laptop will have one IP address when connected to your home Wi-Fi and a completely different one when connected to the school's network. This flexibility allows the internet to remain organized even as billions of devices join and leave various networks every day.

The most common version currently in use is IPv4, which consists of four sets of numbers ranging from 0 to 255, separated by periods (e.g., 192.168.1.50). This format is known as dotted decimal notation. To a computer, however, this is actually a 32-bit binary number. When assigning an IP address, the DHCP server also specifies the subnet mask which distinguishes which part of the address identifies the network itself and which part identifies the specific host or device on that network.

As the number of internet-connected devices has exploded, the world has run out of available IPv4 addresses. To solve this, a newer version called IPv6 was developed. IPv6 addresses are much longer, using 128 bits and written in hexadecimal notation. Hexadecimal notation uses both numerals and letters to represent numbers. IPv6 addresses are expressed as eight numbers separated by colons (e.g. 2001:0db8:85a3:0000:0000:8a2e:0370:7334). This provides an almost infinite number of addresses, ensuring that every "smart" device, from your phone to a classroom thermostat, can have its own unique place on the web.

When assigning IP addresses to devices, system managers choose from three different types of configurations. 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).

Table 13
Differentiating MAC Addresses from IP Addresses

Feature	MAC Address	IP Address
Layer	Layer 2 (Data Link)	Layer 3 (Network)
Purpose	Identifies a device's physical interface on the local network	Identifies a device's logical location on an internetwork
Format	48-bit hexadecimal (e.g., A4:6B:C1:09:3F:88)	IPv4: 32-bit dotted decimal (192.168.1.10) IPv6: 128-bit hexadecimal (fe80::1)
Scope	Local LAN only; never leaves the network segment	Global; used for routing across networks
Assignment	Burned into hardware (though can be overridden)	Assigned by DHCP or configured manually
Used By	Switches for frame forwarding	Routers for packet routing

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 more devices 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 address 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.

Address Resolution Protocol (ARP)

As we've described so far, it may seem as though MAC addresses are used only for LAN traffic while IP addresses are used only for internet traffic. In reality, modern networks are far more sophisticated: essential devices such as firewalls and gateways, core protocols like DHCP, and LANs divided into virtual local area networks (VLANs) all rely on IP addressing even when traffic never leaves the building. This creates a need for a mechanism that links IP addresses to the MAC addresses used on the local Ethernet segment—and that mechanism is ARP.

Address Resolution Protocol (ARP) is the system that connects IP addressing to Ethernet delivery. When a device wants to send data to an IP address on the same LAN, it must first learn the destination device's MAC address, because Ethernet frames can only be delivered using MAC addresses. ARP provides this translation by allowing devices to ask, "Who has this IP address?" and receive the corresponding hardware address in return.

To perform this mapping, a device broadcasts an ARP Request to every node on the local network segment. The device that owns the requested IP address responds with an ARP Reply, supplying its MAC address. This exchange allows the sender to build a complete Ethernet frame with the correct destination MAC, enabling the frame to move one hop at a time across the LAN.

Devices store these mappings in an ARP cache, so they don't need to broadcast every time they communicate.

ARP operates strictly within a single LAN or VLAN—routers do not forward ARP broadcasts—so each network segment maintains its own set of IP-to-MAC relationships. Because ARP underpins all local delivery, incorrect or stale entries can cause communication failures, making ARP a frequent point of troubleshooting in school networks. In essence, ARP is the quiet but essential translator that allows IP-based communication to function over Ethernet's MAC-based, hop-by-hop transport.

Gateways

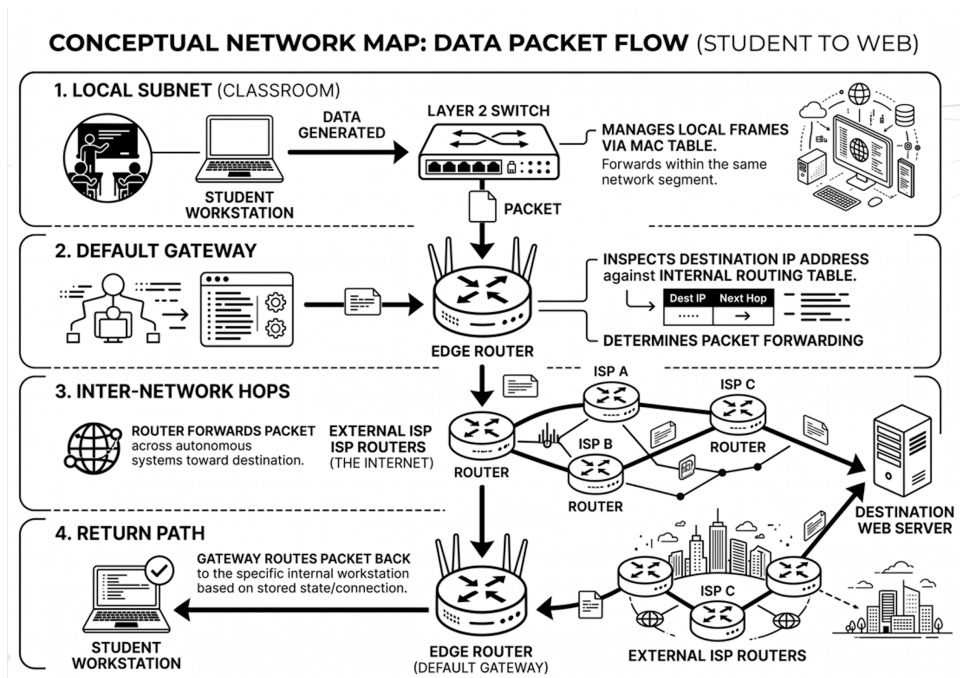
Gateways, which are the devices through which all of the computers on a school LAN connect to the Internet, have at least two network adapters. The external adapter is assigned the gateway's IP address on the Internet which is set by the ISP. All traffic requested from the Internet by a computer on the 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.

Routing

Routing is the process of moving packets of data across different networks. If an IP address is a device's mailing address, then a router is the postal service which is responsible for getting the data to the correct "neighborhood." Once an internet packet passes into your LAN through the gateway, then the routing is done and the LAN sends it to the correct computer. While a switch manages traffic inside a single classroom or building (the LAN), a router is designed to move data between different networks—such as

between your school's local network to the vast world of the internet. Routers act as the gateways of the network; they sit at the edge of the LAN and inspect the destination IP address of every incoming packet to determine the most efficient path for it to take to reach its destination.

Figure 11
Getting Internet Requests to Students



To make these decisions, routers maintain a routing table, which is essentially a master map of the known network paths. Instead of knowing every single computer in the world, a router only needs to know which "gate" or interface leads toward the destination network. When a packet arrives, the router looks at the IP address, consults its table, and "hops" the packet over to the next router in the chain. This process repeats—often across a dozen or more

different routers—until the packet finally arrives at the local network where the destination host resides.

In most school networks, your computer is configured with a default gateway. This is the IP address of the local router that handles any traffic not destined for a local device. If you try to visit a website or send an email, your computer realizes the destination is not on the local school network and automatically hands the data off to the default gateway. Without routing, our networks would be "islands" of connectivity, unable to share information with anyone outside their own immediate physical wires.

Installing and Managing Networks

In schools as in most other buildings, the people responsible for planning and installing networks are not the same people responsible for managing the network. We use vendors to finalize the network plans and perform necessary installations; this work is typically guaranteed, so if something fails, it will be addressed by the vendor under the terms specified in the Service Level Agreement (SLA). Once it is installed, then system administrators, who are employed by the school, keep the networks operational for users, manage shared resources, and take steps to ensure the system is secure.

Planning and Installing

Enterprise networks are incredibly sophisticated and complex systems. They combine hardware and network software that must be scaled for hundreds or thousands of users on campus. There are three adjectives that describe every network if it is in a school or any other business:

- *Reliable*—The network is available (has high uptime) even if a single component fails (it is redundant) and has backup plans operational.

Efficacious Educational Technology

- *Robust*—The network must be available to every user who needs it even during times of heavy load.
- *Secure*—The network and the data stored on it must be protected from unauthorized uses.

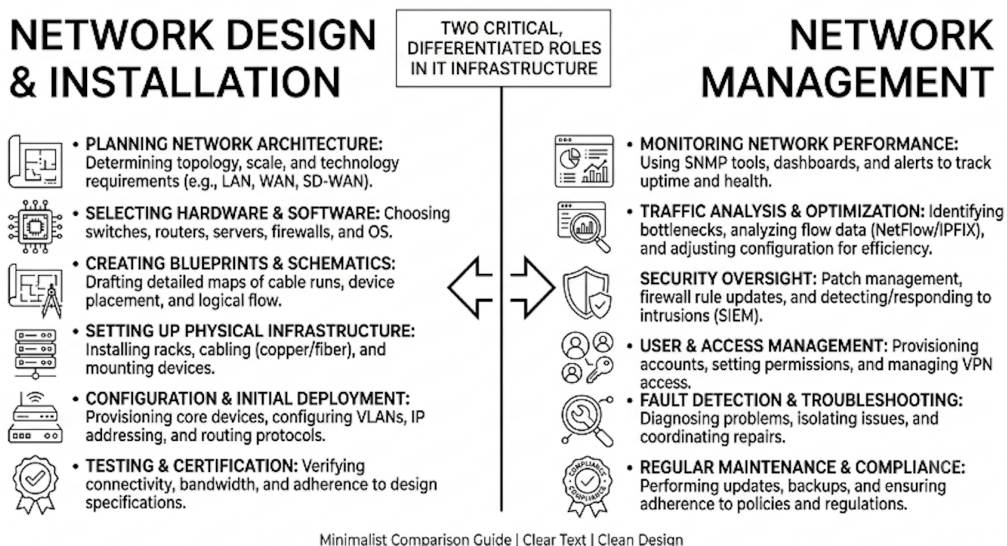
Ensuring a network is all three necessitates expertise in network architecture. Decisions must be made about the hardware and software and configuration necessary to meet the system requirements for the project. When undertaking a major upgrade or new installation of a network, the school IT professionals will work with educators and school leaders to define the requirements, then work with the vendor who will plan and install it. Planning is typically quite detailed. For example, when installing WIFI, the network architects will determine where access points are to be installed to ensure the entire campus is covered and dead zones are minimized.

An information technology network is much like other technologies as the expertise needed to design and build it is much more specialized and expensive compared to 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 require engineers and designers who have detailed expertise and expensive tools, but they are not needed after the automobile exists. Once the network exists, system administrators keep it secure and operational for students, teachers, school administrators and others who use it.

Network installation and upgrade projects are labor-intensive and may cause interruptions in network availability and usually necessitate technicians working 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 short periods of time using 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 who have adequate resources.

Figure 12
Network Planning Versus Network Management



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 manage 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 in 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.

Identity and Access Management (IAM)

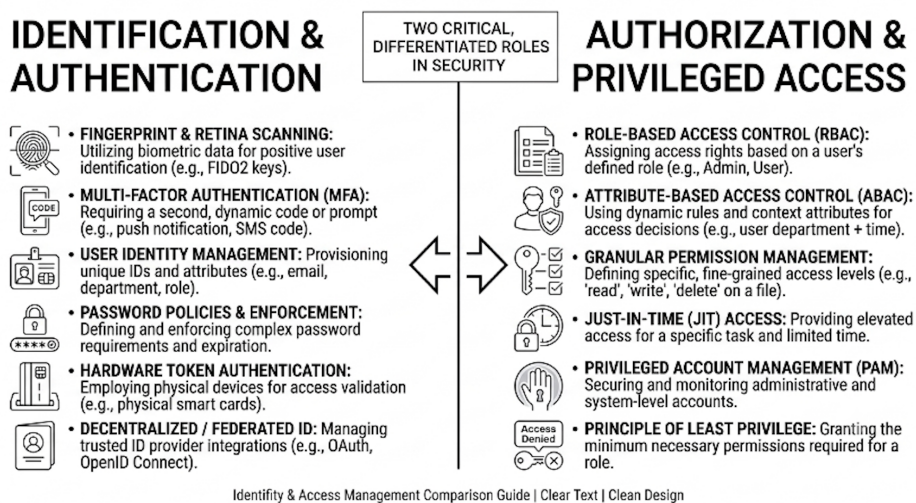
Especially in schools, network users comprise a wide range of people. Not only are some of our users students, but those students demonstrate a diverse set of skills; we have much different expectations of students in first grade compared to high school seniors and the way we manage their accounts and permissions should reflect that reality. We also have adults using our networks, and they also have a different range of use. Some need high levels of access and others have lesser needs for access. We also store important and sensitive information about sensitive populations, so it is vital that school networks have reliable systems of knowing who is at a workstation (identity

management) and what they have permission to see and edit (access management).

Identity Management

When one sits at a computer (or otherwise attempts to access a network), one of the first things the networks “wants to know” is who is the entity making the requests. Traditionally, the entities making requests of networks were people, but today, software can often request access to network resources, especially data. Whether the entity is a person or software, the network software will check their credentials first before allowing any access.

Figure 13
Identity and Access Management



Traditionally, a user verifies their credentials by entering the username assigned to them and entering the password associated with that account. If the two match, then the network “knows” who is there and allows that machine to access the resources that it has permission to view. Passwords, we know, are very unreliable. People write them on notes and stick them to their computers,

a brute force attack can find them, and users will give them to people on the phone who claim to be helping them. For these reasons, when people are requesting network access, they are often asked for other forms of identification.

Authentication schemes are typically organized by:

- *Something the user knows*—Like a password, personal identification number, or answer to a security question
- *Something the user has*—Like a phone to receive a code sent via text message, USB token, or a security card
- *Something the user is*—Like a fingerprint or a recognized face

Multifactor authentication (MFA) can be enabled on many network systems. This means the user must provide more than one way to verify their account before accessing the network.

When LANs first arrived in schools, school IT leaders only had to be concerned with verifying the identity of people on campus. Today's student information systems (SIS) are online, hosted "in the cloud," so we also take steps to verify the identity of parents and other caregivers so they can access SIS, messaging system, and other systems we access remotely.

Access Management

Once the network "knows" the entity requesting the information it will allow access to those resources (such as printers, files, or the internet) that are based on rules; this is called access control. Access management is typically controlled with one or more of several tools including organizational units and groups which organize users, and roles and access control lists. Whenever a system administrator creates rules for access control, they follow the Principle of Least Privilege. According to this principle, if a permission is not explicitly granted, then it is denied.

Organizational units (OU) are available in Active Directory in Windows Server operating systems and similar directory services on both network operating systems and cloud systems such as Google Workspace. Such directory services are created to facilitate permissions of users and management of computers and other devices in the directory. The rules managed by OUs provide a logical structure for managing permissions and they can reflect the organizational structures found in schools, for example, school administrator can be in one OU, teachers in another, and students in a third. While a single user account can be placed in only one OU, they do provide a structure for groups.

Within OUs, group policy objects are used to allow system administrators to configure permissions to enable access to shared resources and configure other network functions such as mapping network drives. These policies give system administrator comprehensive control of the network environment. Once it is created, the policy is then applied to the OU. This allows for efficient assignment of permissions as a policy can be edited once and it is applied to all OUs where it has been applied.

Groups are also used to define permission rules, especially for folders and files. While a single user can exist only in one OU, they can be members of multiple groups. For example, the OU for teachers may include users in the “Science Teachers” group and the “High School Teachers” group. A high school math teacher will be in the “High School Teachers” group, but not the “Science Teachers” group. This illustrates the "multiple membership" benefit of using groups.

When applying permissions on OUs or groups, system administrators typically apply the Standard NTFS Permissions. These give permission to Read, Write, Execute, Modify, or Full Control over files.

Table 14
Comparing OUs and Groups

Feature	Organizational Units (OUs)	Groups
Primary Purpose	<i>Organize directory objects for administration and policy application</i>	<i>Collect users/devices for permissions and access control</i>
Structure	<i>Hierarchical (can contain nested OUs and objects)</i>	<i>Flat (no hierarchy; groups can contain members but not other groups in most cases)</i>
Used For	<i>Delegating admin rights, applying Group Policy, structuring the directory</i>	<i>Assigning permissions to files, folders, apps, printers, and resources</i>
Membership	<i>Objects “live” in exactly one OU</i>	<i>Users/devices can belong to many groups</i>
Affects Group Policy?	<i>Yes—GPOs link to OUs</i>	<i>No—groups do not receive GPOs</i>
Best Thought of As	<i>Administrative containers</i>	<i>Security and access lists</i>
Standard Usage	<i>Used for Environment/System Settings (via GPO)</i>	<i>Used for File/Folder Access (via ACLs)</i>

While Organizational Units and groups provide a logical way to organize users, Access Control Lists (ACLs) are the actual "gatekeepers" attached to specific network resources. An ACL is essentially a digital registry linked to a file, folder, or even a network router, containing a list of users and groups along with the specific permissions they are granted. When an entity attempts to open a document or access a shared drive, the system consults the ACL to see if that

identity appears on the list and what "Standard NTFS Permissions" it possesses—such as the ability to only Read the file or the higher authority to Modify it. By applying these lists to specific resources rather than individual users, administrators can maintain a secure environment where data is only accessible to those with a verified "need to know."

Shared Resources

One of the primary reasons we create local area networks is to centralize storage and management of data and other services. When data are shared on network drives and printers and similar peripherals are attached to the network, users (whose identity has been verified) can access them from throughout the network. Also, we can more efficiently deploy backup protocols and restore data if it is stored in a single shared space. Further, system administrators and technicians can troubleshoot and repair network-connected devices from anywhere on the network. They point their web browser to the IP address of the device, connect to it with an administrator's credentials and can use the on-board web server and interface to access the configuration dashboard.

In the past, shared storage was almost exclusively handled by an on-site File Server—a high-capacity computer dedicated to storing the school's documents. Today, many schools have transitioned to Cloud Storage services like Google Drive or Microsoft OneDrive. While the physical location of the data has moved from a local closet to a remote data center, the networking fundamentals remain the same. The local network provides the "on-ramp" to these services, and the access control lists (ACLs) we discussed earlier ensure that a student can only see their own homework folder while a principal can access school-wide reports. Centralizing this storage allows for version control, preventing multiple conflicting copies of a document from existing on different hard drives.

Shared printing is another cornerstone of the modern school LAN. Rather than connecting a printer to a single computer via a USB cable, network

printers are assigned their own static IP addresses and connected directly to a switch. This allows a Print Server to manage a "print queue," which organizes jobs from dozens of different classrooms and sends them to the printer in the order they were received. Beyond just convenience, this centralization allows administrators to track printing costs, implement "follow-me" printing—where a teacher can tap an ID badge at any copier in the building to release their documents—and monitor toner levels across the entire campus from a single dashboard.

For system administrators, the greatest advantage of shared resources is remote management. Most modern network-connected devices—including switches, wireless access points, and even security cameras—feature an on-board web server. This allows a technician to troubleshoot a device on the other side of the campus without leaving their desk. By entering the device's IP address into a browser, they access a graphical user interface (GUI) or "dashboard." From this interface, they can update firmware to patch security holes, change configuration rules, or reboot a frozen device. This capability is what allows a small IT team to effectively manage a network consisting of thousands of individual components spread across multiple buildings.

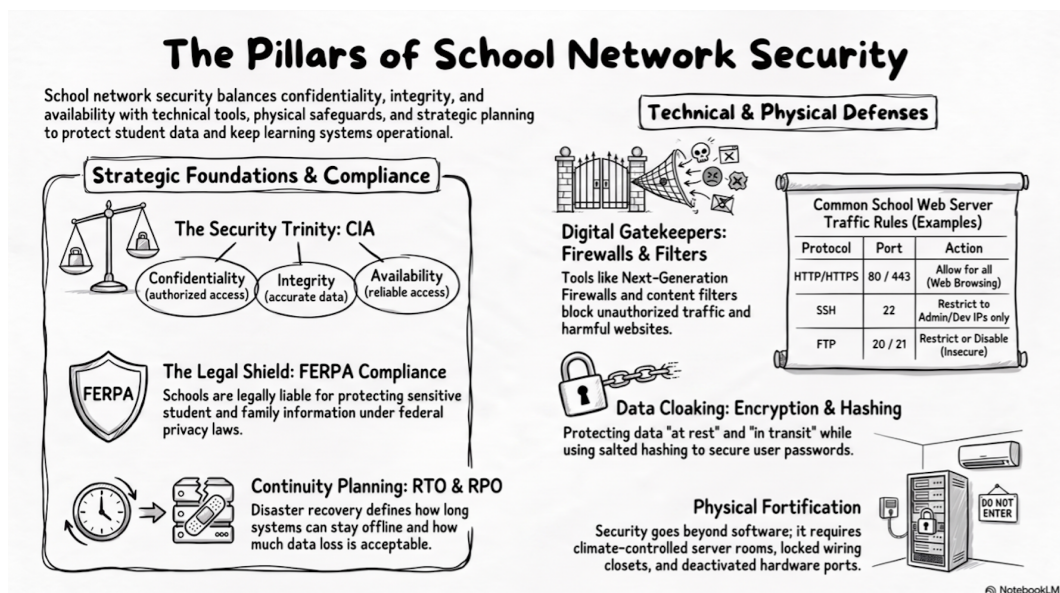
Network Security

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; therefore, 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) (National Institute of Standards and Technology, 2018; Cybersecurity and Infrastructure Security Agency, 2023). 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 is 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.

Figure 14
Aspects of Network Security



Fundamental to network physical security is the security of the servers and other network devices to ensure the devices stay where they belong and are safe. Beyond locking doors to the wiring closets and server rooms, physical security includes ensuring fire protection codes are followed, and the rooms are

properly climate controlled to prevent overheating. Flooding is another physical threat we do not always consider when designing data centers in schools.

Physical Security

Other steps we take to physically protect the local area network are also taken to protect them from software attacks. For example, deactivating unused data ports and preventing access to USB drives on servers protect from unauthorized access, but requires physical actions.

Preventing Unauthorized Access

Computer systems would be quite easy to secure, except for the fact that people need to access them. That is one reason a robust IAM scheme is essential for networks security, but we also take steps to ensure no one else can find their way into our systems.

Operating systems and applications operate in ways that are much more complicated than it may seem when looking at the graphical user interface users see when using a computer. There is software that is operational and unseen, and much of it is open to the internet, even some that was not designed to be open is. These are called “back doors” and they expose users and their computer and the LANs to which they are connected to threats. Hackers can find computers with these back doors exposed and potentially install malware. Security updates may annoy some users, but one of the primary reasons that software publishers release them is to ensure back doors in their software is patched.

Protecting Networks

Firewalls are software tools that restrict the nature of network traffic that is allowed. This software can be configured on end-user devices or on servers or it can be installed as a network appliance, which sets rules for all traffic that seeks to cross the networks. Firewalls are typically configured using either a graphical user interface or commands entered into a terminal. Firewall rules can be configured for incoming or outgoing requests, and they can limit

the protocol being used for the traffic and they can be used to restrict IP addresses.

For example, if one is configuring a web server, then they are likely to allow incoming hypertext transfer protocol (http) and secure hypertext transfer protocol (https) from any IP address and they would allow file transfer protocol (ftp) and secure shell (ssh) connections from the IP addresses of the developers who manage the site.

Beyond simply blocking IP addresses, modern school firewalls utilize Stateful Inspection to monitor the context of network conversations. This allows the firewall to distinguish between solicited data (information you asked for) and unsolicited data (potential attacks), automatically allowing responses to legitimate internal requests. Furthermore, because schools must comply with safety regulations, many deploy next-generation firewalls (NGFW). These devices perform content filtering by inspecting the actual data within a packet to block harmful websites or unauthorized applications, regardless of which port or protocol they are using.

Table 15
Common Firewall Settings for a Web Server

Protocol	Port	Typical Firewall Action
HTTP	80	Allow for all (Web Browsing)
HTTPS	443	Allow for all (Secure Web)
SSH	22	Restrict to Admin/Dev IPs only
FTP	20/21	Restrict or Disable (Insecure)

If filtering is not accomplished through NGFW, then a separate filtering system would be installed on school networks. Filters prevent traffic to and from sites that have been deemed inappropriate for school users. Filters are installed to comply with Children's Internet Protection Act and must be in place for the school to apply for e-rate funds.

System administrators also install malware protection software. This software looks for the fingerprint of known viruses and other malware and either quarantines it or removes it from the computer or servers. Firewalls, internet filters, and malware protection all provide different types of protection, and a comprehensive network security scheme will ensure all are operational.

Encryption

Almost all the data we create in schools is digital. This includes data we are actively using, for example teachers' current gradebooks, as well as archived data, for example transcripts of students' grades. If someone who was not authorized to see the information were to gain access to it when it is being transported over the network or when it is at rest on the server, that would be a threat to confidentiality, so we encrypt our data.

A typical encryption scheme requires two keys; one to encrypt data and a different one to decrypt it. When the first key is used to encrypt your data, the data becomes a random collection of characters. When the data are encrypted, even the patterns that we could use, like the most common letters, are hidden in the encrypted data. To decrypt the data, a separate key that was paired to the first is applied to the data and the original information results.

We do differentiate data that is "in transit" and data that is "at rest." Most data that is in transit, for example email sent using Gmail, is encrypted when it is in transit. The message is then decrypted so that the intended recipient can see it. Increasingly, we are encrypting data that is "at rest" as well.

While asymmetric encryption requires two paired keys, symmetric encryption uses the same key to both encrypt and decrypt information. Because it uses a single key, this method is much faster and more efficient for handling large amounts of data. This makes it the standard choice for protecting data "at rest," such as the files stored on a school's server or a teacher's hard drive. The primary challenge with this scheme is key management; since the same key is used for both ends of the process, it must be kept completely secure. If a person who is not authorized were to gain access to that single key, they would be able to decrypt any of the data that the key protects.

One challenge to data security is passwords, specifically, how does the directory service that authenticates a user verify the password. One might assume it saves each user's password then checks the two are the same. This leads to a potential threat to security, however. If one was able to access the file with the passwords in it, then they would no longer be known only to the user. To avoid this, most data systems use a special type of encryption called hashing to verify passwords.

When one enters their password, it is passed through the hashing algorithm and the results of that are saved to the server. When they log in the next time, the user enters that password, and it passes through the same hashing algorithm. If the results of the hashed passwords match, then the user is verified. To keep this even more secure, most systems use a technique called "salting" before the hashing process begins. This involves adding a unique, random string of characters to the password so that even if two users have the exact same password, their resulting hashes saved on the server will look completely different. This prevents hackers from using pre-calculated lists of common passwords to bypass the security, ensuring that the password remains known only to the user.

Disaster Recovery

Disaster recovery is perhaps the most important task for IT leaders in a school related to network security, ensuring that teaching, learning, and administrative operations can continue even when unexpected disruptions occur. A strong disaster recovery plan recognizes that security is not only about preventing attacks but also about maintaining continuity when systems fail.

Schools face a wide range of threats that can compromise technology systems, and effective disaster recovery begins with understanding these risks. Hardware failures, power outages, cyberattacks such as ransomware, natural disasters, and accidental data loss all pose real challenges. Because schools often operate with limited budgets and aging infrastructure, they can be especially vulnerable. Identifying these threats allows IT teams to anticipate potential failures and design strategies that minimize downtime.

A key step in disaster recovery planning is identifying which systems are most critical and determining how quickly they must be restored. Student information systems, authentication services, file servers, communication tools, and learning platforms typically top the list. Concepts such as recovery time objective (RTO) and recovery point objective (RPO) help schools prioritize: RTO defines how long a system can be offline, while RPO defines how much data loss is acceptable. These metrics guide decisions about backup frequency, redundancy, and restoration procedures. While most would recognize the desire to ensure recovery time is “instantaneous” and all data loss is unacceptable, recovering from a disaster costs money and it may be unreasonable to implement plans that avoid any interference.

Reliable backups form the backbone of any disaster recovery strategy; a backup provides a safety net when systems fail or data becomes corrupted. Schools increasingly use a combination of on-site, off-site, and cloud-based backups to ensure resilience. Versioning protects against accidental deletion, while immutable backups defend against ransomware by preventing attackers from altering stored data. Automated schedules and regular verification ensure that backups are complete, current, and ready to restore when needed.

Beyond data protection, resilient network design helps prevent small failures from becoming major outages. Redundant switches, failover firewalls, multiple internet connections, and virtualized servers all contribute to a more robust infrastructure. Physical safeguards—such as controlled access to server rooms, environmental monitoring, and power protection through UPS units and generators—further reduce the likelihood of catastrophic failures. Together, these measures strengthen the network’s ability to withstand disruptions.

Even the best technical safeguards require clear, documented response procedures to guide staff during an outage or disaster. A strong disaster recovery plan outlines who is responsible for each step, how systems should be restored, and how communication will flow among IT staff, administrators, teachers, and families. Effective communication prevents confusion, reduces

downtime, and ensures that stakeholders understand what is happening and what to expect.

Finally, disaster recovery is an ongoing process that requires regular testing, training, and refinement. Schools must conduct drills, run tabletop exercises, and periodically restore systems from backups to verify that procedures work as intended. As technology evolves and new threats emerge, disaster recovery plans must be updated to remain effective. A well-maintained, regularly tested plan not only strengthens network security but also protects instructional continuity and builds confidence across the school community.

Cloud Computing

The IT No One Touches

For the last two decades, subscribers in schools, businesses, as well as individuals have been able to subscribe to “cloud computing” services. The services make applications for specific purposes (for example managing school finances) or for general purposes (for example productivity suites) available to anyone with an internet connection, an updated web browser, and credentials on the system. Schools make wide use of these, so school IT professionals must be familiar with them.

When desktop computers arrived in classrooms decades ago, we needed to load applications by placing a diskette with the program installed in the drive, then powering the computer on. The single application available to the user was the one on the disk. Using a different application meant removing the diskette, powering the machine off, finding the application you wanted to use, installing the diskette, and rebooting the machine. Of course, data used in one application could not be pasted into another as the information in RAM was lost when the computer was powered off.

When the generation of computers with hard drives arrived a few years later, we still installed software from diskettes or perhaps a Compact Disk (CD), but we installed them on the hard drive, so starting the application meant powering the computer on and finding (by then using a mouse) and double clicking an icon on the graphical user interface to launch the program we needed. We no longer needed to load disks, and multitasking—having more than one application loaded in RAM—became possible, as did copying from one application and pasting into another.

When local area networks became available, it was possible to install application servers, so software was installed on a single server so that users with appropriate authorization could load the software they needed from that

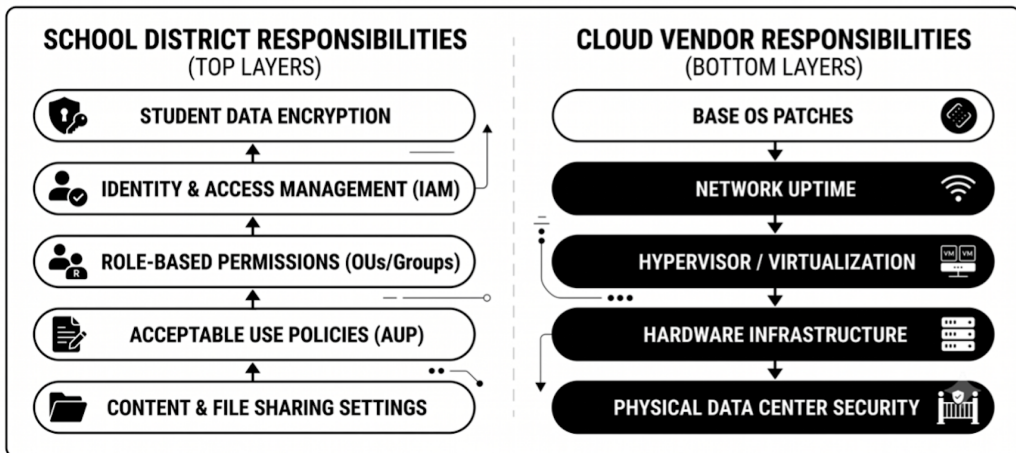
central location. The great advantage for system administrators was that they had only a single location to update when it became necessary.

Today, many applications we use are web applications. The specific software is installed on a web server that has a software engine and the specific application installed. In addition, the data necessary for the users is also stored on the server. Some job descriptions for positions that maintain web applications are called “full stack” to capture the reality that the person will be responsible for all aspects of the virtual server from operating system to web server to application to database management. When you use a cloud service, you are essentially renting the infrastructure, and, depending on the nature of the service, the services of some of the full stack developers employed by the provider rather than hiring your own.

Figure 15

Shared Responsibility Model of Security in Cloud Computing

SHARED RESPONSIBILITY MODEL: CLOUD VENDOR VS. SCHOOL DISTRICT
A DIVISION OF LABOR DIAGRAM



The great advantage for organizations that adopt web applications is that the work of managing systems is offloaded to the vendor. They become responsible for obtaining the servers, then installing, managing, and updating all the software on the system. While the subscribers are responsible for some aspects of the system to keep it robust, reliable, and secure, much of that work is the responsibility of the vendor. When using cloud-based web applications, IT professionals spend less time managing physical servers and more time configuring users' identities, managing their access, securing their data, and fine-tuning their web applications. Cloud systems are based on the shared responsibility model: the vendor is responsible for the stability and security of the cloud, and the subscriber is responsible for reliability and security of the software and data they put *in* the cloud.

Cloud systems serve vastly larger collections of users than a local area network. Despite this, the methods of securing and managing accounts are familiar to those who manage networks in physical data centers. For example, security is based on the principle of least privilege—users typically have no access to resources unless it is specifically allowed in their configuration. Most who can configure policy objects on the network operating system on a physical server can quickly adapt to configuring them on cloud servers as they follow the same types of structures and permissions.

Rationale for Adopting Cloud Computing

The rationale for adopting cloud computing is grounded in scale and economics. We can easily “spin-up” larger servers to meet our expanding needs or turn them off when they are not needed. Because we are using a small portion of a very large system, our share costs less than if we maintained a small system that meets only our needs. In the 2008 book *The Big Switch: Rewiring the World from Edison to Google*, Nicholas Carr described the transition from physical data centers to cloud computing as similar to the transition from generators located at factories and other places where electricity was used to centralized electrical generation stations. In many ways our use of cloud

computing is like connecting to the grid and calling power generated miles away at power stations.

For educational uses, the decision to adopt cloud computing has often been made by the vendors from whom we purchase services; we often have no choice but to use the cloud if we use them. Many schools are subscribers to Google Workspace for Education, which is the dominant cloud provider in the educational technology space. We also access many other services that are cloud-based.

Table 16

The Eras of School Computers Summarized

Era	Key Technology	Management Burden
Early Desktop Diskettes	RAM	High (Manual switching, no data persistence)
Hard Drive Era	Local PC	Medium (Local installation, manual updates)
LAN Era	On-site Server	Centralized (Handled by school IT department)
Cloud Era	Web Browser	Low (Managed by vendor; accessible anywhere)

The reason software vendors have been “moving to the cloud” is grounded in several factors:

- *Scale*—We can scale up or down the numbers of servers based on our needs. When demand is high, we use more resources; when it is low, we use fewer.

- *Cost*—Cloud computing is physically located in large data centers with tens of thousands of servers. This allows for the capital expenses of owning them to be shared among the many subscribers. (The reduced costs are limited to the financial expenses for the subscribers. The hidden costs of pollution and resource reduction for those living near the data centers are recognized as a cost.)
- *Improved security*—Cloud providers are very concerned with security, and their systems are highly secure. If the data and applications you install are secure, then the data you store on the cloud is secure. Some people are concerned about the potential loss of privacy for that data you store on the cloud, but school and technology leaders will vet the systems and their configuration to minimize these risks. While the provider secures the network connections and the servers, the school remains responsible for its own data security practices, such as the encryption discussed in the previous chapter.

As we look back on the history of computing, we see there have been recognizable phases of software development. As systems developed, they became more centralized which led to management by experts rather than users.

Cloud Options

When setting up our cloud-based systems, there are three types of access we choose from when establishing the cloud computing we will build. Infrastructure as a service gives the school the most control but requires a highly skilled IT staff to maintain, whereas software as a service requires almost no technical staff but offers the least customization. Platform as a service is a mix between the two; the vendor manages much of the cloud, but the subscriber manages the applications and their data (Mell & Grance, 2011).

Software as a Service

Software as a service is cloud computing in which the subscriber is using a system spanning the application all the way to the operating system that is controlled by the provider. It is responsible for installing, licensing, updating, and deploying the entire software stack. Users of SaaS have little control over the features and configuration of SaaS systems.

Gmail is a familiar example of a SaaS platform. We can adjust the settings Google has provided for Gmail users, and we are responsible for the ethical and responsible use of Gmail, but all other controls of the software rest with Google. When we use SaaS, we are “stuck” with the changes made by the provider.

Platform as a Service

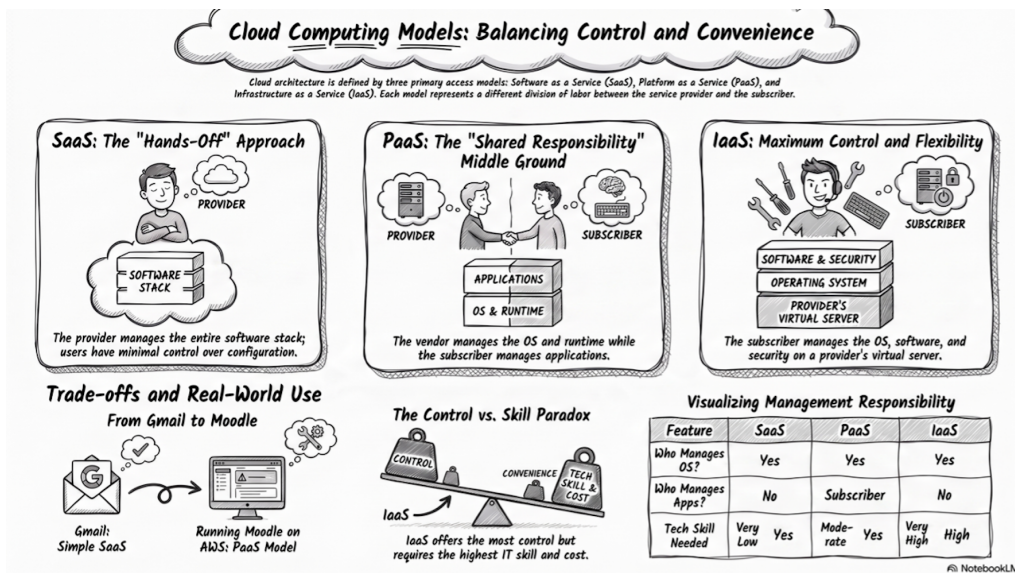
Platform as a service (PaaS) is a version of cloud computing in which the vendor is responsible for the operating system and runtime environment and the programming language. These are all controlled by the vendor, so installation, licensing, and updating are all controlled by them. The subscriber is responsible for installation, licensing, and updating the applications.

An example of a PaaS service that is of interest to school IT professionals and educators is the installation of Moodle (an open-source learning management system) in Amazon Web Service's Elastic Beanstalk. Such an installation would find the following three PaaS being deployed to provide students and teachers with a Moodle LMS:

- *A PHP runtime environment* created on a Linux operating system, both of which are controlled by AWS;
- *The Moodle web application* installed by the user in the PHP runtime environments, which is configured by the school;
- *A MySQL database engine* installed in AWS's Relational Database System (RDS);

- A Simple Storage Service (S3) bucket to store the Moodle data.

Figure 16
Cloud Computing Models



Infrastructure as a Service

Infrastructure as a service (IaaS) is a version of cloud computing in which a virtual server is created for your use. When it is configured, you select the operating system for the server based on the versions available, typically the choices include several versions of Windows, Macintosh, and Linux. Once it is configured, users connect to it via remote desktop or secure shell script or using the graphical interface provided by the cloud provider.

All other configurations of the server, including connecting it to your virtual network; updating the operating system; installing, licensing, and updating applications; and securing the applications and any data created there are all the responsibilities of the user. IaaS installations do provide the most

flexibility to the subscriber, but they require most configuration, and they tend to be the most expensive of the three models.

Cloud Systems Commonly Used in Schools

Many of the data management systems used by educators and those who manage school operations are provided by cloud providers. These applications are provided as a SaaS, so the provider is responsible for all aspects of the system, including upgrades and updates, and they both deploy new features and deprecate other features for the subscriber. Typically, local IT professionals are responsible for administering users from the local populations and managing authorizations based on organizational units defined by local policy and procedures. The structure of the organizational unit and groups are established by the vendor, but they are managed by the subscriber.

These systems tend to be sophisticated for web applications, and they connect to databases to ensure users can access the data they need. Users connect to the web applications using web browsers, and it is often necessary for users to update their web browser to ensure the web application functions as expected.

Productivity Suites

For the first few decades that desktop computers were in schools, there was a variety of productivity suites available. Productivity suites comprise different applications such as word processors, spreadsheets, and since the middle of the first decade of the 21st century, Google has become the dominant provider of this type of software. One of the advantages of using Google Workspace (in addition to the free cost for their basic Google Workspace for Education service) or any other cloud-based productivity suite is they allow easier collaboration. Students can work together on drafts of work, and with a few mouse clicks they can be reviewed by the teacher.

Table 17
Common Cloud Systems in Schools

Tool Category	Core Function	Primary Users	Security / Integration Protocols
Productivity Suites	Document creation, file sharing, collaboration, email	Students, Teachers, Staff	OAuth, Data Loss Prevention (DLP) rules, Domain-level sharing limits
Learning Management Systems (LMS)	Virtual classrooms, assignment collection, online testing, gradebooks	Teachers, Students, Parents	LTI (Learning Tools Interoperability), OneRoster API, SIS sync
Student Information Systems (SIS)	Master student records, state reporting, attendance, official report cards	Administrators, Registrars, Teachers, Parents	FERPA compliance, strict Role-Based Access Control (RBAC), multi-factor authentication (MFA)
Business & Operations Applications	Payroll, human resources, building automation (HVAC/ Security), VOIP	District Leaders, HR, Facilities, Operations	Network VLAN segmentation, encrypted API endpoints, strict IP whitelist rules

Microsoft Office is another very popular productivity suite, and there are others that are far less widely used. One of the major advances in productivity suites has been the integration of file formats. Previously, if one did not have the application installed on their computer, and if the files had not been saved in a universal file format, such as rich text format (.rtf) for word processing

files, then it could not be opened. Today, we upload Word files to Google Workspace where they are opened by Google Docs. Some file formatting is lost, and some advanced features of Word files are not converted, but most content is copied from Word into Docs. Further, a Google Docs file can be downloaded as a Word file. We can do similar file conversions with Apple's word processor, which is called *Pages*.

When Microsoft was the dominant productivity suite for school users, they had Word, PowerPoint, Excel, and Access to provide word processing, presentations, spreadsheets, and database functions. As cloud-based productivity gained acceptance with Gmail and what came to be known as Google Workspace, additional apps were added to productivity suites. In addition to email clients or webmail, we find calendars, to-do lists, video conferencing, forms, web publishing, artificial intelligence agents, and many other applications integrated into productivity suites.

The one way we can return to the "good old" days of installed productivity suites is to install and use one that is open source. While these are available at no cost to users, including schools, they do necessitate more work to install and manage them. LibreOffice and OpenOffice are commonly installed suites. In general, these follow the standard word processor, spreadsheet, presentation, and database model, but typically lack the integrated email and calendaring found in Google Workspace or Microsoft 365.

Systems for Teaching and Learning

Especially with the use of Chromebooks as the dominant tool of choice for schools, many of the applications once used in classrooms have become cloud based. Typically, school leaders will manage connections to their instance of the platform by either enabling single-sign-on which allows users to connect (for example) their Google credentials so that they can use their Google account to log in to the cloud provider. Alternatively, the providers of the cloud-based application will prepare an application programming interface (API) link that allows users to connect to the school's license. When individuals follow the link,

they are added to the database of school users, which can then be used to ensure they do not exceed the number of seats licensed by the schools.

The software available as cloud-based teaching includes:

- *Games for instruction*—These include games to teach math facts, tutorials for touch typing, study guides for exam preparation, and similar tools once called “edutainment” software.
- *Simulations*—These are used for case studies in which students assume a role and make decisions based on information provided to them, and they are also widely used in science courses for dissection or to demonstrate experiments that cannot be safely done in class.
- *Math construction tools*—Math students and teachers can easily create graphs and geometric models with these tools, plus they can be measured with precision using the tools provided in the workspaces.
- *Multimedia Editing Tools*—Cloud-based tools are available for editing audio and video files.

These tools largely replace applications which were installed on hard drives on desktop computers, and they are single-purpose tools. There are other cloud-based web applications that provide far greater capabilities than single-purpose software.

Learning Management System

Learning management systems provide virtual classrooms. These are used in virtual schools, where students never meet in person, but they can also be very useful for courses in which students physically meet either occasionally or all the time. Teachers use them to extend their classrooms and enhance information sharing and interaction. Like other cloud-based infrastructure in

schools, the learning management system (LMS) managed by school IT professionals are usually provided by a vendor either as SaaS or a PaaS.

Learning management systems are used to recreate many classroom functions commonly found in face-to-face classrooms. Access to the classroom is restricted to those who are enrolled as teachers or students (or other roles), and different users have permissions appropriate for their role. For example, students can upload assignments or take tests but cannot see others' submissions or test attempts. While the exact features depend on the LMS that is used and how it is installed and configured (including what optional features are enabled), every LMS provides features to allow:

- *Sharing information*—When using LMS teachers never have to worry about students saying, “I lost the paper;” when files are shared in an LMS, they can log on to it and get a new copy. In addition to word processing documents, multimedia presentations, audio, video, and portable document format (PDF) files, teachers can create pages with links, embedded media, and other items. The what-you-see-is-what-you-get (WYSIWYG) hypertext markup language (html) editor available in LMSs includes equation and chemistry editors and other tools that allow teachers to create sophisticated pages, including embedded media and cloud-based files.
- *Interact*—Discussion boards, wiki, blogs, chat, and other tools for online interaction are available on LMSs as well. These are used to replicate the information sharing and knowledge building that happen in face-to-face classrooms, although the asynchronous nature of some of these tools does change the dynamics of the interaction for students and teachers.
- *Administer tests*—One of the most useful tools in any LMS is the ability to create tests that can include many different types of questions. For many teachers, the most useful are those that can be graded by the LMS (assuming, of course, that the correct answers are accurately identified).

Setting up online tests can be a very labor-intensive endeavor, as there can be significant individual data elements that must be input, but once the test is created, it can be shared, edited, remixed, and reused.

- *Collect assignments*—Digital drop boxes are also one of the most useful tools in an LMS. Using this tool, instructors define an assignment and create a digital drop box in which students can upload a file that contains their submission. The problem of lost assignments or students arguing, “I handed it in, you lost it,” is avoided when work is submitted to an LMS.
- *Record grades*—The gradebook in every LMS can record and display items from tests and assignments with grades associated (and grades can be automatically recorded for those items). Teachers can also add columns to the gradebook to record items that are done offline. Teachers can further organize the gradebook by assigning grade items to categories, setting weights to categories, adding calculated columns, and setting display conditions for items. Gradebooks are notoriously complicated, in many cases because the language used to describe the configuration is unfamiliar to teachers.

Google Classroom is the LMS associated with Google Workplace. Because of the dominance of Google and the fact it is integrated into the productivity suite used by the teachers and students, many adopt it. Some teachers who have experience with a full learning management system either as a student or as a teacher find Google Classrooms to be too limited to accomplish much they want to do. There are a number of LMSs that are available in hosted services, so they are SaaS to minimize the need for expertise to manage it.

There are multiple full-feature LMSs available, both as open-source packages and as proprietary packages. Full learning management systems include platforms such as Moodle, Blackboard, Canvas, Desire 2 Learn, among many others. The selection of the LMS is made based on several considerations.

While Moodle is often chosen because it is available for free, the cost of installing it on a server (either one in the school or a virtual server on the cloud) can introduce unanticipated costs. Other considerations include familiarity which can increase the perceived ease of use for both teachers and LMS administrators. Perhaps the most important consideration is the degree to which the IT professionals, including the technology integration specialists and other instructional leaders, are prepared to provide support, training, and design guidance.

Student Information Systems

Schools are organizations that require information to be kept about students; this data supports both internal operations as well as reporting to external entities, a task which has gained importance in the decades since *No Child Left Behind* was adopted. The student information system is the term applied to the databases that are designed to collect, store, and report information associated with students' school experience.

One difficulty for school and technology leaders is to decide on which tool to use for gradebooks. While an LMS typically has a gradebook, the SIS has one as well. It may be easier for faculty to manage grades in the LMS as that is where they interact with student work. It is possible to connect the LMS gradebook to the SIS gradebook, but this typically necessitates programming and database expertise provided by the SIS provider to configure and to troubleshoot.

The SIS is a large database that contains multiple tables related to students' attendance, course enrollments, academic performance, health, discipline, and other records. Many SIS will also contain tables and tools to facilitate scheduling. Because many SIS are available on the cloud, parents and others can access the SIS. In many ways, the SIS is the most essential IT system maintained by the school IT professionals.

In addition to ensuring robust, reliable, and secure networks so that users can have uninterrupted access to the SIS, IT professionals play several

roles specific to these platforms. They ensure user accounts are accurate; in most cases, this includes ensuring a single sign on tool is configured and secured. They work with registrars and others to ensure data are accurately entered when students are registered and that data are sent to other schools when students leave. They also write scripts and set other controls to ensure data are available and analyzed in a manner needed by regulators and by internal audiences.

There are several vendors that provide student information systems for schools. The SIS that has been selected and deployed depends on many factors, and it is not unusual to find SIS that have been used for many years in schools. IT professionals are likely to be asked about their experience supporting the one that is in use. Some schools have replaced traditional grades with “standards-based report cards” which has necessitated modification of the SIS.

Choosing an SIS is a task requiring the deep collaboration of school and IT leaders. Often, however, the decision is made to ensure each school in a region has the same SIS.

Library Catalogs

When I was an undergraduate in the 1980s, the university I attended still had card catalogs; long drawers with index cards that described the books in the collection. (Actually, three cards to describe each book with one organized by title, one by author, one by subject) When I returned to the same university as a graduate student two years later, the cabinets full of drawers had been replaced with computers.

Those computers probably connected not to the cloud, but to a database on campus that contained the index of the collection. Rather than opening drawers and looking at cards to find the books we wanted, we sat at a computer then entered the title or authors. Technically, we could also search by subject, but I always found it better to find a book I was interested in on the shelf, then look around it for others that might be of interest too. Years later, I managed

school library card catalogs, again stored on local servers, but I did configure the network to allow students and teachers to search from off campus.

Today, most libraries connect to a SaaS system that has had their card catalog uploaded. I am sure my configurations were not as secure as a modern cloud-based system. IT professionals are likely to be responsible for configuring the API to allow students and teachers to log in, but do not really have much else to do with them. The librarians manage their collection and upload MARC (machine readable cataloging) from their library vendors.

Full Text Databases

Full text databases are another cloud system used by librarians. A full-text database comprises indexes, abstracts, and sometimes the full-text of periodicals. Exactly what is available to library patrons depends on the subscription of the library they are using. In many cases, access to full text databases by institutional users like schools is controlled by a URL specific to the institution. Allowing access to off-site users requires that the link be protected by a password, so that only those individuals who can access the institution's intranet, for example, can access it.

Business Operations

Cloud systems are widely used for business operations as well as for teaching and learning. In many cases, these systems are identical to the ones used in organizations other than schools.

Human Resources

Human resources functions, including applicant tracking and interviewing, are very common in schools. In some cases, these can dissuade applicants from applying for jobs as the software requires application to copy and paste from their resume into individual fields to complete the applicant tracking database. An HR system can also be used to track forms, for example those used for tracking employees' supervision and evaluations. HR systems can

Efficacious Educational Technology

further be used to track background checks and fingerprinting, which is a common requirement for working in schools.

Financial Services

A cloud-based financial services web application allows schools, districts, and higher-education institutions to manage budgeting, purchasing, payroll, and reporting through a secure online platform rather than on local servers. Because the system runs in the cloud, updates, backups, and security patches happen automatically, and staff can access financial data from any device with proper credentials. These applications typically integrate with student information systems, HR systems, and procurement tools, giving administrators real-time visibility into spending and compliance. For educational technology leaders, cloud-based financial platforms reduce the burden on local IT teams, improve data accuracy, and support transparent, audit-ready financial operations across the institution.

Building Management

Buildings are now connected to the internet. Building management software is used to control and manage heating, ventilation, and air conditioning systems; fire alarms; locks and security systems; lighting and power management; and other systems. Cameras are installed for security purposes in schools, as well as many other public spaces, but they can often cause controversy in schools especially when they are placed near restrooms and in or near classrooms.

Voice Over Internet

Beginning early in the century, voice over internet protocol (VOIP) systems began arriving in schools. VOIP is used for delivering telephone calls over internet connections rather than plain old telephone lines. In general, VOIP tends to reduce cost of telephone service, and it integrates voice mail and emergency services.

As access to internet connections expanded, largely through the use of E-rate, VOIP was installed in schools. E-rate is a federal program that helps

schools and libraries in the United States afford modern internet access. Created by the Federal Communications Commission (FCC) and administered by the Universal Service Administrative Company (USAC), the program provides discounts that make essential networking services more affordable. These discounts typically range from 20% to 90%, depending on a school's poverty level and whether it is in a rural or urban area.

E-rate funding is divided into two categories. Category 1 supports services that bring internet into the building, such as broadband connections and wide-area networks. Category 2 funds the equipment inside the building that makes internet use possible—Wi-Fi access points, switches, cabling, and related hardware. Since its launch in 1998, E-rate has played a major role in expanding digital learning by ensuring that schools have the connectivity needed for online resources, classroom devices, and modern instructional tools.

Social Media

Social media platforms are not typically understood as a cloud computing service, but they are SaaS which allows immediate publishing to the internet. We use either apps on smartphones or web sites, and when logged on with our accounts, we post text, audio, or video and it is instantly seen by anyone or only those who follow our accounts or only others who we give permission to see the contents.

These platforms have been a difficult aspect of the digital world for school to navigate. There is evidence that social media use by young people is having an adverse effect on their social well-being (Office of the Surgeon General, 2023), and it has been very difficult to regulate access to the sites even from schools as smartphones bypass the filters used to control access to web sites on school networks. Further, adults using social media can become closed to outsiders, and especially if there are adults who work in schools participating in those groups, there are issues of privacy and even public open meeting laws that may arise.

One practice that is unfortunately common, in my opinion, is posting images or videos of students on social media or on web sites. Those who do this assure me that they have a waiver signed by the parent indicating they have permission to share the images and that those who do not have waivers are not included in images. Waivers are grounded in informed consent; those agreeing to have their or their children's images displayed are made aware of the purposes for which it is to be posted. While the school's purpose for the image may be clear, other potential uses are not. For example, if a student's image that was posted on a school social media post gets included in an embarrassing meme, then it is hard to claim the parent agreed to that use of it. Further, we are dealing with children, and we should not be asking them for consent on such public displays; we should be asking students' consent in safe places, but the public display of their image is not one.

While school and technology leaders should be careful about social media, there are ways that it can be useful. Consider these examples:

- *An athletic director* creates an account and uses it to make announcements for student-athletes' parents. Last-minute changes to schedules are posted as are updates during games. Perhaps the most interesting use is when storms interfere with games. They and the officials huddle in safety, and each time they hear thunder or see lightning, they post an update. Families sheltered in their cars or otherwise waiting in safety can have updates about game status.
- *A parent group* creates a social media page to announce fundraising and other events. The site allows for the participation of parents who work during the regularly scheduled meetings of the parent group.
- *A group of teachers* each travel hundreds of miles (from different directions) to attend a conference. They begin chatting after a session, and find they have a common set of problems and are interested in each

other's solutions. They follow each other on social media and become valued long-distance colleagues

- *A math teacher* encourages students to work problems in groups. After students present their solutions to the class, model solutions are selected. If the solution was done on a tablet (or other technology) a picture of the screen is posted by the teacher. If the solution is on a piece of paper (or other media), a picture is taken and then posted (along with appropriate alternative text). The teacher's feed of solutions becomes a permanent resource for students.
- *A librarian* has students write reviews of their favorite books under pen names. She posts them on a social media account, and the feed is embedded in the school website.
- *A student* volunteers to use a web camera to live stream sporting events; this could be done with other events like plays and concerts, but there is the potential that use may violate copyrights.

Large Language Models

Large language models and other variations of generative artificial intelligence have become widely available since late in 2023. These sites are cloud-based SaaS. They are integrated into *Google Workspace for Education* and the tools provided by many other cloud service providers.

The use of generative AI in education settings has been highly contentious. In many cases, it has been decided to block access to the tools from school LANs. While this may prevent some use, it does not stop students from using AI to complete assignments. Some educators maintain the position that AI should be allowed in schools so that teachers can model its appropriate use (UNESCO, 2023).

Part 3: Reasonable Implementation

As suggested by the subtitles of the three chapters in this section ("rules we should follow," "rules we decide to follow," and "rules we must follow"), schools are places where rules determine much of what we do. When we are students, these rules are often hidden from us. Students see the rules defined by teachers and principals as arbitrary, and in some cases, they are. By recognizing the nature of the rules we follow, who decides them, what motivates the rule makers, and the results of following or ignoring them, we gain a better understanding of why we do what we do. We also have a better chance of explaining these rules to students or to others who are unfamiliar with their rationale.

Theories and Educational Technology

Rules We Should Follow

Scholars define theories which inform the work we do in education. As practitioners, we are not obligated to ground our work in theory defined by scholars, but we should. There are several well-established theories that are useful for guiding the decisions of educational technology leaders.

Education is an active field of research. There are scholars at universities around the world doing experiments and other types of studies in which they seek to understand how technology affects learning. The ideas researchers define are called theories. In common language, “theory” is often synonymous with “wild guess” and theory is the opposite of fact. Researchers do proceed from intuition to hypothesis to theory that is supported from different perspectives. During this process, intuition and hypothesis are challenged and refined, so theories do become well-established.

In this chapter, I describe well-established theories of how technology affects learning. While theory is often dismissed by educators and educational technology professionals, it does allow us to streamline processes by ignoring irrelevant factors. The reality is educational technology professionals who ground their work in valid theories are more effective and they can explain their decisions in a way those who ignore it cannot.

I argued in the Introduction that frameworks are grounded in theory and are useful for guiding organizational decisions. In this chapter, I describe some of the theories that have been used to ground efficacious educational

technology. Most of these have been used for decades; they may be rejected, but they are more likely to be refined.

Introducing Theories

Theories do explain the way the world works in idealized situations, and this makes sense as they are typically developed in the laboratory or other controlled settings. Schools are places that are not controlled, but that does not mean theory does not apply. It does mean that schools are natural environments where complex interactions happen between individuals who vary.

How Theories Arise

The “gold standard” of research used to develop theories is the double-blind random experiment. When researchers conduct experiments, they review existing theory and define a gap in the theory. This gap is clarified in a research question and a method for answering it is approved. Experiments find a sample of the population being randomly selected, and the individuals in the sample are divided into the treatment group and the control group. The research method comprises a strategy for ethically gathering and analyzing the data, including the statistical methods used to address the research question. The double-blind nature means the individual conducting the analysis is unaware of which group was the treatment group and which was the control group.

When we conduct experiments, we collect quantitative data, which is analyzed with statistics to test hypotheses. While experiments can be conducted in some educational settings, in many cases, educational researchers seek other sources of quantitative data to answer their research questions. They also use descriptive statistics to document trends and to describe populations. In addition to collecting data with surveys or questionnaires, qualitative data can also be collected with observations. For example, trained observers can record how many events of interest occur in a classroom, and with digital data and

cloud computing used in so many educational settings, data collected through those systems can be studied as well.

Educational researchers also collect qualitative data to answer interesting questions in educational technology. Qualitative data are recorded as text and can include individual or focus group surveys; they can also emerge from document analysis such as meeting notes or recording transcripts. Whereas quantitative data are analyzed using descriptive or inferential statistics, qualitative data are usually read and coded by multiple readers. These codes are used to either describe and detail the themes the researchers have agreed are relevant, or the coded data are used to write profiles of relevant users.

Once researchers have asked a question, developed a hypothesis, gathered and analyzed the data, they submit it for publication. Other researchers review the article, and once their concerns have been resolved, it is accepted for publication. Before the theory becomes established, it is replicated in similar and different settings. After more studies have validated the theory, it may become established. This is when practitioners should begin using it.

It is important for practitioners to wait until a theory is established before they begin to rely on it to guide decisions. A common phenomenon in recent decades has been the replication problem. New “discoveries” are made in research; in many cases the findings are new and may get attention because they are novel. The new findings, however, are not replicated. There may be a problem with data collection or analysis; the findings may have been the result of error.

How We Use Theories

Educational researchers are almost always in search of interventions that will improve learning. When designing experiments to accomplish this, the changes made are called the independent variable and learning is the dependent variable. It is reasoned, “we can change instructional strategies independently” and “learning depends on the strategies we use.” (This makes

perfect sense until we realize that measuring learning is very difficult, and what constitutes learning in one study is not measured in another.)

When we analyze experimental data (or any other quantitative data), we create scatter plots in which the independent variable is plotted in the x-axis and the dependent variable is plotted on the y-axis. Using this strategy, we can visualize how the two variables affect each other. We can see positive associations, which means that when the independent variable increases, the dependent one increases as well. We can also visualize negative associations, so that as the independent variable increases, the dependent variable decreases. We can also see when there is no effect between the variables.

We can also use graphs to visualize qualitative data. On Figure 17, perceptions are the dependent variable, so they are displayed on the x-axis. Notice the data are qualitative, so different words describing students' perceptions mark the extremes. Interest is the dependent variable, so the y axis shows low interest to high interest. The curve demonstrates how students' interest changes according to their perceptions of the technology, media, or activities. When these are familiar, students are likely to be bored. When it is perceived to be too novel, students find it incomprehensible, so they have low interest. This graph suggests a moderate level of novelty (or complexity or unexpectedness) increases interest which leads to learning.

The left side of this curve, from boredom to novelty indicates a positive association between perceptions and interest. As students perceive moderate levels of novelty, interest increases. On the right side of the curve, we see a negative association between perceptions and interest; as things become too complex, interest decreases.

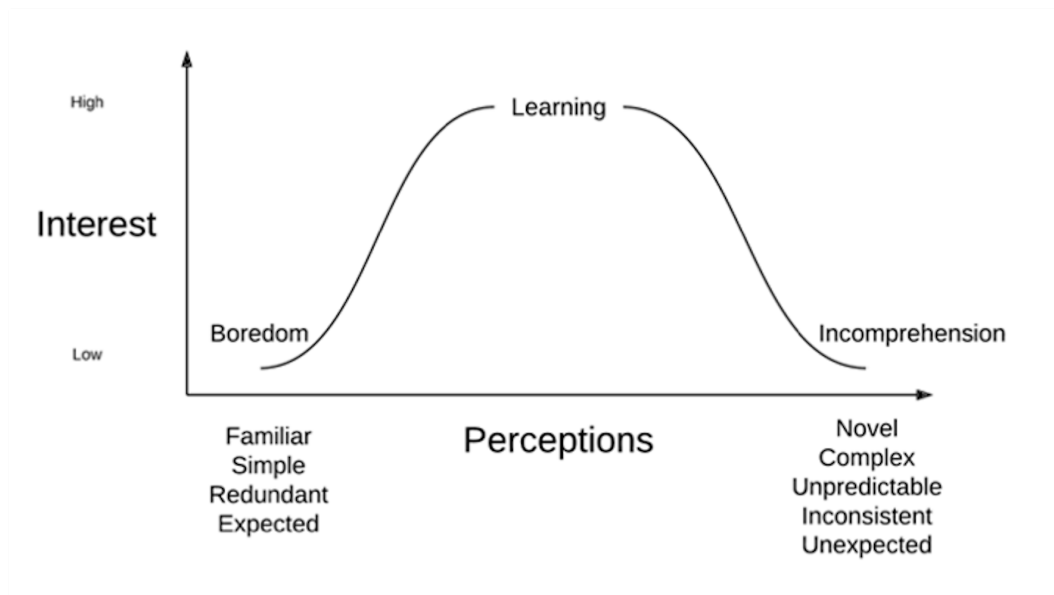
The theory illustrated in this graph demonstrates how theories affect our work. We know from this theory that some novelty in media and technology promotes learning, but it does not specify how much novelty is appropriate for any classroom setting or any individual student. We can predict from this theory that students with low interest in a lesson may be bored or it may be incomprehensible (Seels et al., 2004). It is educators' job to decide which it is,

and it is our job as educational technology professionals to support their efforts to make it more or less complex to seek to maximize interest, and hence, learning.

The relationship between interest and perceptions gives an example of the appropriate way IT professionals can ground decisions in theory without allowing it to interfere with our practice. A technology integration specialist who is familiar with the theory captured in Figure 17 may observe a classroom as they use technology and observe students' lack of interest and suggest a change in how the technology is used to change students' perceptions to adjust the level of novelty to be more appropriate. This change can be made without referencing the theory or explaining it other than with a simple statement to the teacher such as "I think the students may have been a little bored, let's change things up a bit for the next class."

Figure 17

Students' Interest Versus Their Perceptions, adapted from Seels et al., 2004



In the preceding paragraph, we saw how IT professionals can change what they do using theory without specifying it. In other cases, they do want to be very explicit about how they use theory. We know that ease of use is positively associated with the intention to use technology (more about that later). Ease of use has been studied by researchers, and they have developed instruments (the term researchers to describe surveys) to measure it. IT leaders may want to measure ease of use over time to document how changes in their practice are affecting how people are using technology in the school. To do that, they would want to detail the theory they are using and the instrument as well as they conduct measurements.

When using theory—and the instruments that have been used to measure the variables—to make decisions, IT leaders can focus on the parts of their practice that matter. Using surveys to collect users' opinions is a common way to gather data in schools (and in other organizations). If we use an appropriate instrument when we craft our surveys, we avoid collecting irrelevant data.

Parsimony

When a theory is parsimonious it is the least complex it can be. An example of increasing parsimony in educational research comes from the myth of learning styles (Pashler et al., 2008). According to this theory, individual students learn best when the materials is presented in their preferred style. For example, “visual learners” were supposed to learn best when materials were presented in graphs or images. As work to establish this theory continued, it was discovered that learning styles do not exist. There are some materials that we all learn better when presented visually, and we learn better when we interact with material in different modes.

It turns out we can explain how different media affects learning if we ignore learning styles. By removing learning styles from learning theory, we made it more parsimonious. It turns out we should make material available in

many formats (something you support as a school IT professional), but we do not need to justify it by “learning styles.”

Relevant Theories

There are several theories that are important for information technology professionals who work in schools to understand. They are germane to identifying key priorities during decision-making and they help to provide a rationale for those who are uncertain of the direction we take our departments and the direction we take when leading and managing IT in schools. Many of the theories in this section are not specific to educational technology. The same theories that affect technology use in other situations have been found to apply to school as well.

Technology Acceptance Model

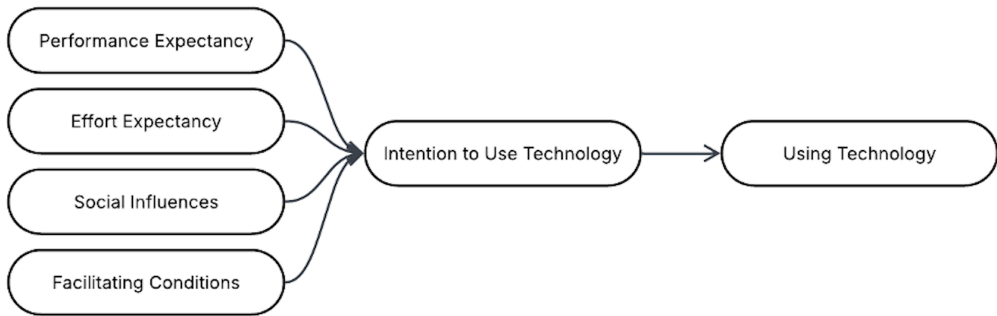
The technology acceptance model (TAM) was first elucidated by Fred Davis in 1989. The research was motivated by Davis’s observation that organizations had spent significant amounts of money on information technology, but that many users still did not use it. Davis suggested “that performance gains are often obstructed by users’ unwillingness to accept and use available systems” (Davis, 1989 p. 319), so TAM sought to identify the independent variables that affect individuals’ intention to use technology. If we are trying to increase the use of technology, then we should take steps that are positively associated with technology acceptance in our work.

In the decades since it was first defined, technology acceptance has continued to be an active field of research, and it has been used in many situations. In 2003, technology researchers defined the unified theory of acceptance and use of technology (UTAUT) (Venkatesh, Morris, Davis, and Davis, 2003) which consolidated multiple theories into a single theory. UTAUT is a widely used version of technology acceptance. According to the UTAUT, four factors are directly associated with users’ acceptance of technology and

their patterns of technology use: performance expectancy, effort expectancy, social influences, and facilitating conditions. All of these are positively associated with the intention to use technology, so efforts to increase these tend to increase the intention to use technology, thus its actual use.

Figure 18

Factors Directly Associated with Technology Use, adapted from Venkatesh et al., (2003)



Performance Expectancy

Performance expectancy, sometimes called effectiveness, is a measure of the extent to which an individual believes the technology system will affect how well they will do their job. When PE is greater, they believe the IT system helps them to be effective in their work, and they are more likely to use it.

Effective performance is rooted in outcomes and relative advantage. For educators who are using IT in their instruction, outcomes will be defined by the goals they have for students in their classroom. One challenge for school IT professionals is that outcomes may be different for different teachers or for different parts of their curriculum or even for different students. Teachers who believe that their job is to prepare students for standardized tests may perceive technology differently compared to those educators who believe their job is to prepare students to create high-quality public performances. Of course, the same teacher may have very different and even seemingly contradictory goals. As a mathematics teacher, I may want my students to have access to a

web-based platform that gives practice problems designed to improve basic computation skills. This “teaching by computer” method is likely to result in learning that is easy-to-document. I may also want my students to have access to multimedia tools that allow for scripting so that they can explore fractals (for example) which will produce learning that is difficult to document. The easy-to-document learning may be associated with improved performance expectancy, or it may not. It depends on the goals of the lesson.

Fundamentally, teachers make use of information technology (at least since Aristotle, as suggested in the first paragraph of the book); even analog tools, such as pencils and paper and whiteboards, are information technologies. Relative advantage can come from improved efficiency. If an educator believes they can teach more or more quickly using a digital technology, then they are likely to use it. For example, teachers tend to find they are more efficient teaching graphs (or data to be interpreted with graphs) using spreadsheets rather than have students draw each graph they need. Relative advantage can come from better learning. If digital graphs help students develop stronger understanding of the material, they are associated with greater relative advantage. Some digital graphing tools also allow for sliders, for example, to illustrate how different coefficients or constants affect the shape of the graph; this can help students develop a stronger sense of how they change the appearance of the graph.

It is not unusual for teachers to select relatively primitive tools because they represent a good level of obsolescence for teaching what they need to teach. A librarian colleague and I once discovered a Compact Disk with *Oregon Trail* on it. It was about 15 years old at the time, and it was built for Windows computers about three generations old. We decided to try to install the game and were surprised to see the familiar boot screen and music. A teacher overheard the music and came to look at the screen. She took the disk, intending to use the game for an upcoming middle school language arts lesson, “now my students will learn non-fiction writing just like I did,” she said.

Effort Expectancy

This is a measure of the individual's perceptions of how easy it is to use the IT systems. Perceived ease of use exerts strong influences on decisions to use technology in the periods after initial training has occurred, but before the user becomes highly familiar with and skilled using the system. When first learning to use a technology system, the simple work of remembering what one is supposed to do interferes with the ease of use. For this reason, when new technology is adopted, school leaders and technology leaders will find alpha and beta testers before the technology goes into production. It is also why onboarding procedures for new educators and staff includes training in how to use the specific systems in use in the school.

The same technology can be perceived as having different ease of use for different users. IT professionals who ground their work in technology acceptance will understand that it is the users' perceptions of ease of use that matters more than the IT professionals' own perceptions. IT professionals who use systems all day and everyday must recognize that teachers who use the SIS to report grades (for example) only a few times each year may find it more difficult than they do.

Social Influences

Educators are affected by what others do just like all other humans are; when it comes to using IT, it seems educators are particularly affected by others. Social influences (SI) have complex roots emerging from the individual's perception of what people they deem influential value in technology. An individual's cultural experiences and expectations, and the social status that can be gained or lost by their use of technology also influence SI.

These influences may be contradictory. For example, if a CIO who has little teaching experience recommends a new platform, it may not be accepted by educators because of negative social influences. Alternatively, educators may advocate IT professionals install and configure IT systems similar to those

used by their colleagues in other schools. New educators may be influenced to use technology based on the role of IT or the tools they used in their teacher education program, which may be very different from what they encounter in their first professional position. Younger educators may also have different cultural experiences, including an acceptance of IT, that are dismissed by older colleagues who minimize the role of IT in the classroom. (The stereotypes contained in that example are recognized. While research does suggest there is a weak association between age and IT acceptance and gender identification— younger and male individuals tend to have greater acceptance—IT professionals cannot justify drawing any conclusions about IT use based on age or gender identity in today's schools.)

Social psychologists recognize three types of social influences. Social influences that result in compliance are typical of settings in which individuals are obligated to act in a defined way to gain reward or avoid punishment. Educators who are required to use a particular online grading system may comply with the request but not use the advanced features of the reporting system. When individuals feel a strong identity with another individual (or with a group of individuals) then the individual will seek to model the actions of that individual or group. The social influences resulting from those identifications tend to be stronger than the social influences of compliance. The strongest social influences arise when the individual internalizes the social influences and thus, they become perceived as natural and the individual holds the same expectation of others.

Facilitating Conditions

There are a range of technical and organizational factors that contribute to an individual feeling supported in their use of IT systems. For educators, these factors include financial resources, troubleshooting and repair expertise, training opportunities, as well as perceptions that they can influence technology decisions. In schools where educators perceive all these resources have been adequately provided and necessary procedures are in place, then they are more likely to use the technology.

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 assumes 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; everyone 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 any information 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.
- *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.
- *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.

In general, intrinsic cognitive load depends on the task. When physics students solve a problem, they must conceive of how to solve it regardless of the technology. We can use technology to maximize germane cognitive load by

minimizing extraneous cognitive load. For example, the physics students who use a graphing calculator to solve the problem can minimize the extraneous cognitive load associated with drawing the graphs they need to solve it.

Table 18
Comparing Types of Cognitive Load

Load Type	Definition	Classroom Example	IT / System Administrator Goal
Intrinsic Load	Inherent complexity of the learning material itself	Productive cognitive effort dedicated to processing and mastering content	Managed by curriculum; IT provides appropriate tools (e.g., graphing calculators)
Extraneous Load	Wasted cognitive effort caused by bad design or confusing tools	Struggling with complex login steps, broken links, or clunky navigation	Minimize / Eliminate: Implement Single Sign-On (SSO), clean LMS layouts, and reliable hardware
Germane Load	Productive cognitive effort dedicated to processing and mastering content	Analyzing patterns, solving problems, and building mental models	Maximize: Free up total cognitive bandwidth so students focus purely on learning

Technology such as the graphing calculator does not automatically reduce extraneous cognitive load. 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), however, 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 how 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. For example, a learning management system may be used for simple tasks at first. For example, a teacher who uses it as a digital drop box first may use the LMS to administer online quizzes once it is familiar, then for online discussions when it is even more familiar.

Social Construction of Technology

Technology is designed for a purpose. Teams of engineers and designers work with technology, envision a purpose for it, develop and refine prototypes, test it, then put it into production. Then users begin to interact with it. Users may begin using it for the intended purposes, but they often discover new uses of technology; the problems they solve never envisioned by the original designers, they invent new strategies for how to use it. Social construction of technology (SCOT) is a theory about how technologies emerge then become widely accepted by users (Pinch & Bijker, 1984).

According to SCOT, any use of technology in a setting, for our purposes we can focus on classrooms, emerges out of the meaning users make of it in social situations. This suggests IT professionals can put any technology they want in a classroom, but it does not mean anything until students and teachers use it. Interpretive flexibility is the term used by SCOT researchers to describe

the fact that different groups of users can use the same technology for very different purposes.

Interpretive flexibility is negotiated by a relevant social group. These groups are using technology to solve problems they have identified, and the negotiation finds them attempting solutions, trying them out, and revising them. In effect the users become the actual designers of the solutions. As these solutions are better adapted to solve their problems, the members of the socially relevant group stabilize their use of technology for that problem on the best ones. SCOT researchers call this closure.

SCOT is a theory best used to explain and predict technology use, but it is not often used to define independent variables. Observers can see how socially relevant groups are organized, how they are designing solutions, when negotiations are underway, and when they are nearing closure, but they are unlikely to predict the outcomes created by users-turned-designers.

Activity Theory

Activity theory has a long history, originally developed by Lev Vygotsky, a Russian psychologist who is very influential for some educators and remains widely cited today. Vygotsky had wide-ranging ideas about how the brain works, and activity theory captured his thoughts on how brains and technology influence each other in complex and meaningful ways. Activity theory has been refined by other researchers in the years since Vygotsky originated it, gradually evolving into a more comprehensive framework used across many educational and technological contexts.

While Lev Vygotsky provided the foundation by focusing on how tools mediate human thought, Yrjö Engeström expanded Vygotsky's ideas into a collective system (Engeström, 1987). The strength of activity theory is its use in identifying contradictions. When a new technology is introduced, it often creates “disturbances”—such as a clash between new digital tools and old institutional rules. For example, you may see schools banning cell phones for students, but that contradicts teachers' intention to use them in class. By

analyzing this contradiction, we may be able to modify rules to allow for the desired outcome.

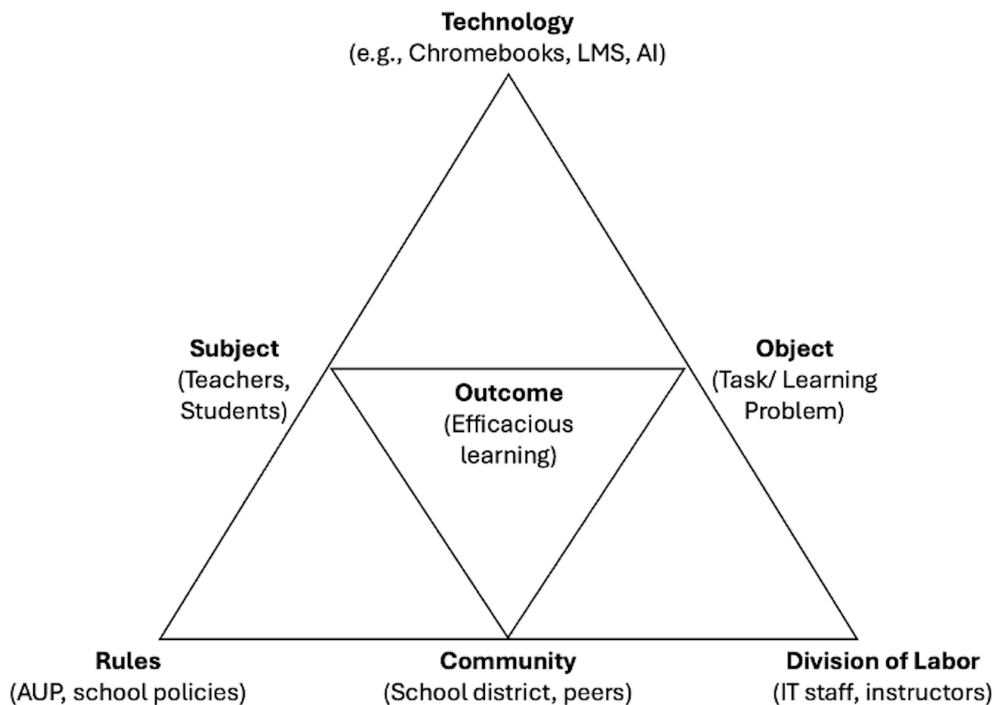
- *Subject*—The individual or group that is engaged in the activity. For school IT professionals, this would include students and teachers primarily.
- *Object*—The problem the subject tries to solve. We have seen there are different types of goals that guide actions in schools; any of those goals can be the object of a system being studied with activity theory.
- *Tools*—The technology being used to solve the problem. Today, this is most often digital technologies, but activity theory works no matter the nature of the technology.
- *Rules*—The policies that determine how the technology and the object operate. In schools, this would include policies as well as norms of behavior.
- *Community*—In activity theory, the subject and object typically are understood to form a social group.
- *Division of labor*—The social group includes different people who perform different goals; this division includes the designers of the tools.
- *Outcome*—The system under study is intended to result in some outcome. In schools, the outcome is likely to be improved learning among the students.

When using Activity Theory to frame technology-mediated interactions, a diagram featuring two interconnected triangles is often used to clarify the many factors associated with the theory. This visual representation highlights how subjects engage with tools to pursue an object or goal, while also being influenced by rules, community expectations, and the division of labor within their environment. The second triangle emphasizes the dynamic relationships

among these elements, illustrating how contradictions or tensions can emerge and drive change within the activity system. Together, the paired triangles provide a concise yet powerful way to depict the complexity of human–technology interactions and help researchers and practitioners better understand how learning, teaching, and technological practices evolve over time.

Figure 19

An Activity Theory Triangle for Efficacious Educational Technology



Just as with social construction of technology, activity theory is a theory for understanding interaction with technology in social groups, especially when those interactions unfold within complex educational settings. These theories

are used to frame problems and interventions, helping researchers identify patterns of practice and sources of tension, so independent variables are less important for these theories than in others that focus more narrowly on measurable outcomes.

Technological Determinism

Technological determinism is a theory that has emerged from the work of Thorstein Veblen and continued by several authors including Lewis Mumford and Marshall McLuhan. McLuhan (1964) famously posited that “the medium is the message,” suggesting that the inherent characteristics of a communication technology have more impact on society than the content it carries. Whereas social construction of technology and activity theory regard technology as existing within social systems and the social system largely determining how the technology is used, technological determinism suggests a much more dominant role for technology. Once technology is invented, according to technological determinism, it develops on its own logic and affects society. Among the important ideas of technological determinism are:

- *Technology’s influence on history*—Major changes in history, according to the determinists, have been the result of technology.
- *Technology is autonomous*—How technology emerges is not influenced by human decisions.
- *Society adapts to technologies*—The behaviors of individuals and groups change in response to technology.
- *Human agency is limited*—People respond to technology rather than influencing it.

Technological determinism is usually described as existing on a continuum. Strong technological determinism suggests a strong deterministic

effect; technology has direct influences on society and those effects are unavoidable. Soft technological determinism suggests technology enables change, but that people continue to determine how it affects what we do.

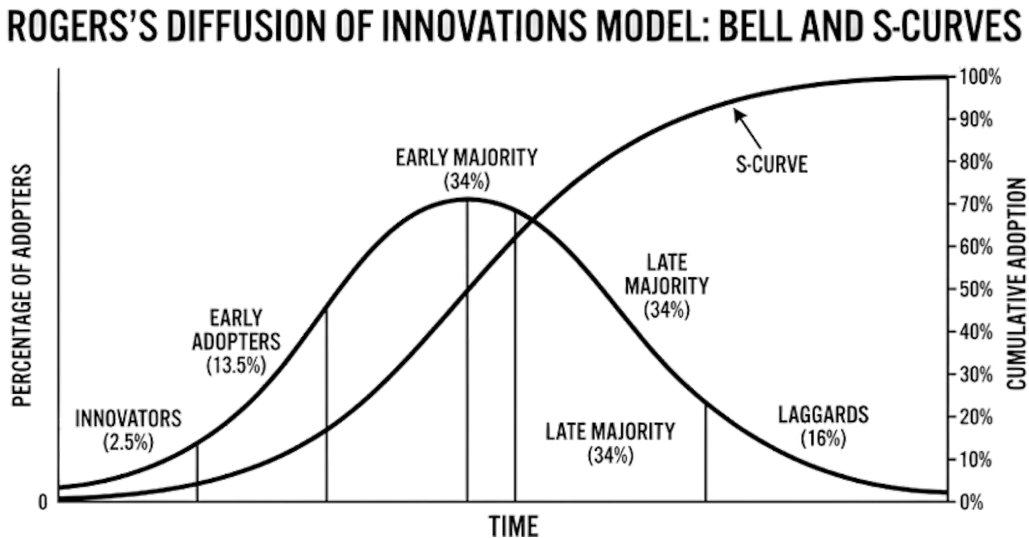
The current phenomenon of generative artificial intelligence in schools has all the signs of technological determinism at work. Many aspects of school have been challenged by this technology, even leading to question “Is schoolwork even necessary?” (Young, 2026). We also see that technology is emerging on its own and we are having little influence on how it is affecting school.

Diffusion of Innovations

Once an innovation enters a community, and begins to diffuse, its adoption occurs as the populations accept 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 Everett Rogers 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.

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 having 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.

Figure 20
Roges' Diffusion of Innovations



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 most of the population is using an innovation, the late majority adopters yield to increasing expectations that the innovation be used as well as respond to 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 used the term later adopters to describe the last group to adopt an innovation. 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 by this group derives from many 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. As we have seen, however, some may not adopt an innovation because an obsolete one has greater relative advantage.

While it is easy to categorize late adopters as resistant, Rogers (2003) cautions against the pro-innovation bias—the inherent assumption that every innovation is inherently good and should be adopted by everyone. By recognizing this bias, educational leaders can shift from blaming the teacher for not using a tool to investigating whether the tool itself is truly efficacious for that specific classroom context.

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Table 19
Summary of Theories and Frameworks

Theory / Framework	Key Concepts	Application for IT Leaders	Primary Focus/ Type
Technology Acceptance Model (TAM / UTAUT)	Performance Expectancy, Effort Expectancy, Social Influences, Facilitating Conditions	Guide onboarding, design user-friendly systems	Quantitative / Predictive
Cognitive Load Theory (CLT)	Intrinsic Load, Extraneous Load, Germane Load	Simplify interfaces so students focus on learning	Cognitive / Individual
Social Construction of Technology (SCOT)	Interpretive Flexibility, Relevant Social Groups, Closure	Adapt tools in real classroom contexts	Qualitative / Social
Activity Theory	Subject, Object, Tools, Rules, Community, Division of Labor, Disturbances/Contradictions	Align tech rules with pedagogical goals	Systemic / Structural
Technological Determinism	Autonomous Technology, Medium is the Message, Limited Human Agency	Evaluate emerging, disruptive tech	Philosophical / Societal
Diffusion of Innovations	Innovators, Early Adopters, Early Majority, Late Majority, Late Adopters (S-Curve & Bell Curve)	Identify adopters and avoid pro-innovation bias	Organizational / Adoption
TPACK Framework	Technological, Pedagogical, and Content Knowledge (7 intersecting domains)	Ensure technology connects with teaching	Instructional / Pedagogical
SAMR Model	Substitution, Augmentation, Modification, Redefinition	Evaluate whether tech use enhances or transforms learning	Integration / Level

Other Frameworks

In addition to theories relevant for decision-making, several other frameworks that are useful but that lack the evidence that typically supports theories. These are widely used in framing technology decisions and deserve similar attention that we give theories. Frameworks were described in the Introduction; the ideas described in this section share the characteristics described there.

TPACK

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). 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 models as a separate type of knowledge. It is reasoned that as information technologies become more familiar, their existence as a separate type of knowledge decreases. Technology pedagogical content knowledge was updated to include an "A" (TPACK). It has become a very useful framework for understanding teaching and learning in the technology-rich school. While TPACK 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).

As a framework useful to inform IT management decisions in school, TPACK 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 TPACK within a school community can be evaluated from an individual’s perspective (what is the current TPACK of each and how can it be improved), and from the perspective of the entire faculty. Social influences are known to be an important determinant in technology acceptance (Venkatesh & et al., 2003), everyone’s TPACK is affected by the group’s TPACK, and the TPACK of influential individuals are even more important in affecting the group TPACK.

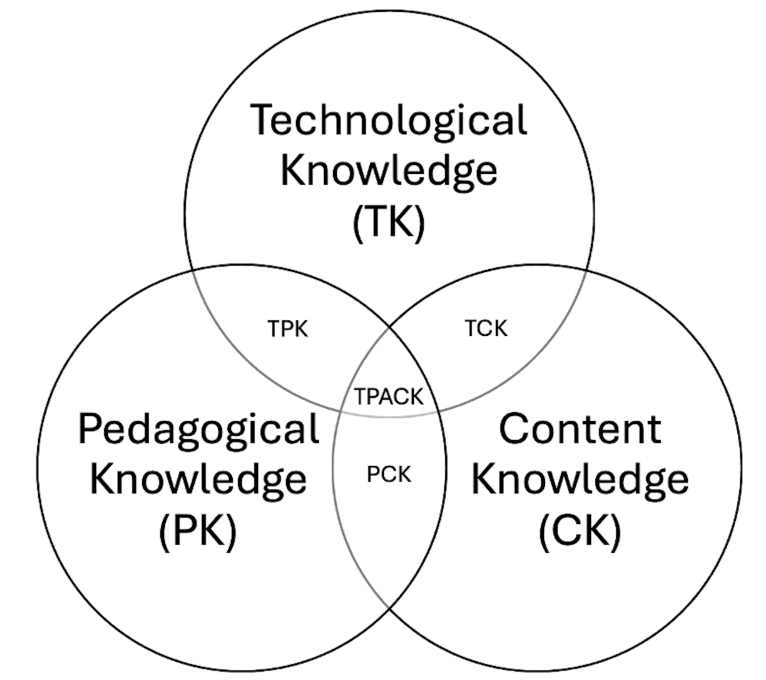
TPACK is proposed as a dynamic framework and Mishra and Koehler (2006) anticipated it would change over time. Shulman (1987) did not differentiate books, pencils, paper, and other information technologies into a separate type of knowledge when PCK was first elucidated; he reasoned those were transparent technologies and a stable part of teaching and learning for generations, thus no specific knowledge was necessary to use technology. It is likely that computers and associated technologies will become more transparent, so TK may become a less distinct type of knowledge. 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 TPACK into the foreseeable future. Further, the nature of the classroom determines how TPACK 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 TPACK, 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 that educators need to provide efficacious experiences. In addition, TPACK facilitates understanding of who must be involved with decisions and who must lead and participate in training, curriculum development, and other professional development activities.

Figure 21

The Seven Domains of Teacher Knowledge According to TPACK, adapted from Mishra and Kohler, 2006



SAMR

The SAMR model, developed by Dr. Ruben Puentedura (2006), is a framework that describes how technology is used in classrooms. SAMR focuses exclusively on technology integration; it provides a framework for evaluating the degree of transformation that occurs when moving from analog to digital

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instruction. SAMR is an acronym for four types of technology integration: substitution, augmentation, modification, and redefinition.

Substitution is the first level of technology integration. With substitution, technology is used, but the nature of the teaching or the nature of the activity for students does not change. Typical examples of substitution are using a word processor to type an essay rather than writing it by hand, reading books displayed on a screen rather than a printed copy, or completing worksheets by completing questions presented in Google Docs.

Table 20
SAMR Model Summarized

Stage	Description	Classroom Effects
Substitution	Tech acts as direct substitute with no functional change (e.g., typing an essay instead of pen)	Some enhancement
Augmentation	Tech acts as direct substitute with functional improvement (e.g., spell-check, instant quizzes)	Enhancement
Modification	Tech allows for significant task redesign (e.g., collaborative real-time audio editing)	Some transformation
Redefinition	Tech allows for creation of new tasks, previously unimaginable (e.g., global video sync)	Transformation

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Augmentation is similar to substitution, but the technology improves the efficiency of what is done or it provides a functional improvement. Examples of augmentation include using the spell checker and grammar tools in a word processor, using the dictionary built into the viewer to quickly check definitions in a PDF file, and using digital quizzes to get immediate feedback.

Modification is integration that changes how the lessons are created and extend and enhance how information is analyzed and created with digital technology. Examples include using file sharing to enable collaborative writing assignments, the use of digital tools to capture and graph experimental data and creating podcasts or videos as alternatives to written assignments.

Redefinition finds students engaged in tasks that they could not have completed without the digital tools. Examples of redefinition include engaging with remote participants via video conferencing, the use of simulations to experiment with unsafe settings, and the use of large datasets available from organizations like NASA.

Typically, substitution and augmentation are types of integration in which technology is used to enhance teaching and learning, while modification and redefinition are transformational. When pedagogy is transformed, it allows students to complete tasks that cannot be done without technology. While it seems that redefinition may be the goal of integration, SAMR is typically presented as a framework that promotes the “correct” integration. Educators find the level that best meets their needs.

Procedures to Support Reasonable Implementation

Rules We Decide to Follow

Procedures are the recipes we follow to ensure necessary work is properly completed. When we are dealing with information technology, these recipes include procedures for ensuring devices are properly configured, including properly secured, and others for ensuring devices are available when they are needed by the people who need them. Most schools also have procedures in place for decision-making related to technology.

In the previous chapter, I described theories, which are ideas about how humans as individuals and in groups—including within schools—interact with technology. These are ideas that we should follow, but we need to be careful as some theories can be contradictory, especially when we are addressing education, which is a wicked problem. Frameworks are based on accurate information, so when creating frameworks, we define their theories which will determine what is “true” for those who follow it. Notice that, while we are working with theories and frameworks, we are following principles for how we should accomplish our work.

While we know that effectiveness is associated with the intention to use technology in the technology acceptance model, that theory does not tell us how to go about making it more effective. In organizations, procedures comprise the rules for how things are done. In schools where we find efficacious educational technology, we find alignment between the goals and the procedures, but there is also alignment between relevant theories and procedures.

It is the primary responsibility of school and IT leaders to ensure the procedures used to manage IT infrastructure and schedule resources are

aligned with the policies of the school (policy is discussed in the next chapter). The IT leaders then take the procedures they created with school leaders and implement them with the members of the IT department. In this chapter, I describe procedures we follow to ensure IT is aligned with the goals of the organization, theories, and the limits imposed as school leaders seek to manage reasonable implementations.

Managing Devices

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 because computers were simply replacing other technologies; for example, the middle school students I observed while I was an undergraduate replaced graph paper with printed versions of their results. Most of the information the students created and consumed 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 have come to dominate, computers have become vital to how information is accessed, analyzed, and created in diverse classrooms. With this change, it has become essential that malfunctioning computers be repaired in a timely manner—with ‘timely’ being defined in hours or days rather than weeks (Marrone & Licker, 2015). Especially in schools where one-to-one initiatives 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 arises from broken computers.

Table 21
Strategies for Resolving Malfunctioning Computers

Strategy	Operational Mechanism	Key Primary Benefits	Administrative/Technical Limitations
Imaging	Overwrites the local drive with a standardized, updated system image file via network or USB	Rapidly restores system to a "known good" state; clears deep corruptions and malware; automated background process	Model-specific image management; permanently erases un-backed-up local data; consumes high network bandwidth
Freezing	Background software protects configuration state, reverting all system changes upon reboot	Eliminates software-induced faults from multi-user lab devices automatically without technician intervention	High commercial software cost; requires external cloud/network storage for user files; can delay OS patches if unconfigured
Inventory Swapping	Maintains extra identical hardware units to replace malfunctioning student/teacher devices immediately	Minimizes classroom downtime to zero; lets student resume learning instantly while repair takes place	Requires additional capital budget for spare fleet inventory; requires hardware consistency across models

In the previous chapter, we saw that the technology acceptance model suggests the facilitating conditions are a factor associated with the increased use of technology. A robust system that ensures technology is kept in good repair is one such facilitating condition.

Interestingly, many malfunctioning IT systems 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 these software problems can be avoided or resolved with a few strategies: a) imaging allows technicians to reset the software on entire systems, b) freezing prevents changes to the software on systems, and c) 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 a copy of a computer hard drive, then sending that copy to the hard drives of other computers. Technicians generally use the term “imaging” to describe either the process of creating an image or the process of deploying it to other computers. This strategy is particularly useful in situations where there are many 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 are established, printers are 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 we can use keyboards, network adapters,

displays and similar tools to load the software needed to create and receive the image file. Third, the software imaging software are used to either create an image file or receive it.

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.
- *Systems used to create images must be thoroughly tested before the image is made.* 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 the image is deployed. Technicians must confirm all settings are correct to avoid the need to repeat the process.
- *Some configurations 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 specifics 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 on target machines that has not been backed 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 repairs, 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 quickly.

Freezing

While imaging is a process that requires the intervention of a technician to reverse a software problem, freezing is a strategy that automatically prevents changes to the software or configurations of a computer. Just like imaging, freezing begins with all updates and applications **being** installed, the network properly configured, and network printers and other peripherals 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 that *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 hardware reasons will find a technician

who removes the hard drive (containing the operating system, applications, network settings, and the student's 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 device 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 expanding the capacity for technicians to perform repairs remotely. While this may appear too obvious to be necessary to state, 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 perform repairs; this can be by providing the technicians with more training or better work conditions or hiring additional technicians to share 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 coincidentally 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 perform 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 types of repair are delayed. For these reasons, when on-site technicians are placed 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 to log on to desktop and laptops computers from 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.

Ticketing

The web-based services for managing repair requests 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 move on to new assignments.

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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 one 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. This point and the previous point are examples of how the system facilitates 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. This point and the previous point are examples of how the system facilitates communication between the IT staff and the rest of the community.

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 warm closure.

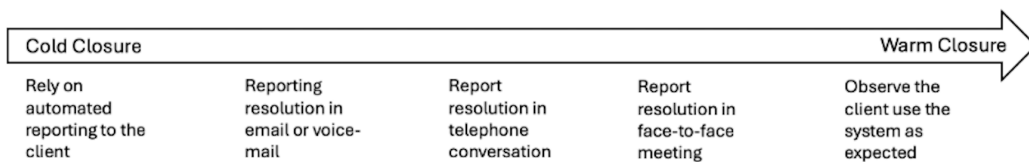
A warm closure occurs when the technician speaks with the individual who reported it and confirms the issue has been resolved. In the ideal situation, direct closure is done in-person, but a telephone call or voice mail are better than cold closure. A teacher who hears, “let me know if it does not work,” 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 who reported the problem inaccurately describes it or describes a situation with incorrect terminology, then the technician can arrive at the computer and not accurately observe the malfunction reported by the user. Because the technician did not see the (inaccurately) reported symptoms, they close the ticket and move on to other

work. The individual who reported the malfunction may return to the machine to discover it still malfunctions because the technician made no repair or they 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 in 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 received," 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.

Figure 22
Cold Closure Versus Warm Closure



Triaging School IT

IT systems fail; all IT professionals (and all IT users) know this. The reality is that the “to do” list for IT professionals in schools is often too long to allow immediate resolution of every system that someone believes to be failed. Further adding to the reality is that not all failed systems can or even should be fixed, and many IT professionals find teachers are very reluctant to abandon old systems that provide a useful and familiar instruction application, but at some point, continued repair is not possible.

Triaging is the work of prioritizing what gets fixed and the order in which it gets fixed. This sometimes requires balancing reactive repairs with proactive improvements, and time used for one is not available for the other.

All IT professionals understand that one of the most important things to do after starting a new position in IT support is to identify “the complainers.” These are the people who give the best feedback on the functionality of the systems, they raise concerns immediately (as opposed to other users who try to manage with less-than-optimal technology), and they tend to be the individuals who use the systems the most and for the most purposes. The IT professional who can satisfy this group will generally be perceived to be responsive and effective.

IT professionals must develop skill in triaging calls for IT support to decide what gets immediate attention and what waits until later. Unfortunately, there are no rules that guarantee the correct triage decisions will be made. Many factors which are described in this section affect triage decisions, and a situation that is given high-priority one day may be given a lower priority another day.

The Eisenhower Matrix is a method for helping people prioritize the tasks they have to do. It is named for Dwight D. Eisenhower, the United States president who was famous for saying “I have two kinds of problems: the urgent, and the unimportant. The urgent are not important, and the important are never urgent.” It uses urgency and importance as two dimensions, so it created

a 2x2 matrix with “unimportant” and “important” usually displayed as the rows and “urgent” and “not urgent” displayed as the columns.

If you can find tasks that are not important and not urgent, then it is best to avoid them. In organizations, however, we are often asked to attend meetings that we deem unimportant and that almost always are. Asking for a meeting agenda can help avoid unnecessary meetings or at least allow you to be present only when the items requiring your input may help are discussed. It does not always happen, but it is worth an attempt to avoid unnecessary items on your to-do list.

Table 22
Eisenhower Matrix

Eisenhower Matrix	Urgent	Not urgent
Important	I: Crisis Tasks with strict deadlines or consequences if they are not met	II: Strategy Tasks with no deadlines or consequences, but that are aligned with goals
Not important	III: Interruption Tasks that require attention, but that are not aligned with goals	IV: Waste Tasks with no deadlines or consequences and are not aligned with goals

Tasks that are urgent but not important can occupy the time of many school IT professionals. The concept of importance is based on perceptions in these cases. The Eisenhower matrix is based on the individual’s perceptions. For IT professionals, creating a disaster recovery plan or completing a network map may be very important. For a classroom teacher, those projects are important, but making sure the projector works so their students can view the video they had promised by their teacher is very important. (The most stressful IT situation is being in the classroom full of elementary students who are

waiting for the projector to work.) As a result, teachers arrive in the IT suite asking for immediate troubleshooting for a task they could easily manage by restarting the computer.

Perhaps the most important quadrant for IT leaders in schools is the not urgent, but important quadrant. Tasks such as preventive maintenance and training are typically found in this chapter, but they can be among the most important for the long-term sustainability of the IT we manage. If these tasks are delayed as we manage urgent problems, then they can become urgent, and often urgent with disastrous consequences as systems fail or security is breached.

One of the challenges for IT professionals is to prioritize meaningful deadlines and consequences in an attempt to make more time available for important but not urgent projects such as the disaster recovery planning and completing the network map. The “complainers” who I suggested can be among the most important users for IT professionals to pay attention to are useful in deciding how to prioritize as well. They often help us decide which tasks are important and which are not. Here is a list of other factors to consider when triaging school IT problems:

- *Safety*—It is an unfortunate reality that IT can be used to create unsafe situations. If there are threats, bullying, or other potentially unsafe situations and your expertise is needed to document, investigate, and remove those threats, that needs to be given highest and immediate priority.

During the weeks when an assistant principal was dealing with a particularly serious cyberbullying situation (it was sufficiently serious that the police were involved), he would ask me to “help fix the color printer in his office” if I was working with or near students or teachers. He did not have a color printer, so we arranged this code so he could request immediate help without drawing attention. When he used that phrase, I knew that I should secure whatever I was working on and go directly to his office.

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- *Legality*—It is also unfortunate that IT can be associated with situations that can present legal liability. These may be associated with unsafe situations, but they can also be associated with human resource issues or other circumstances in which safety is not threatened but data needs to be secured or actions documented. These also receive highest priority. When dealing with issues related to safety or legal issues, no IT professional should be working without school administrators being aware of the situation and participating in the decision-making. Ideally, school administrators would be present when any work was being done on such matters and they will both direct the IT professional to take necessary steps and receive frequent and detailed updates on what is happening.
- *Large numbers*—Every IT professional knows steps to “fix the problem that will get the most users back up” get high priority. This rule of thumb applies in school as well.
- *One-time events*—Teachers often arrange for their students to have special opportunities that will not repeat such as field trips and guest speakers. Because these events cannot be easily rescheduled and because they represent very valuable opportunities for students, these should be given high priority when they are scheduled.
- *Students*—Because schools are hierarchical organizations, certain people can be understood to be of higher priority. It seems reasonable that school administrators should be given the highest priority as they are the most politically empowered individuals. It is difficult to justify this decision, however. Whenever I am faced with prioritizing and one of the problems has direct impact on students, then that one goes to the top of my priority list. It should be noted that not all who are in leadership positions or teaching positions agree with my priorities.
- *Beginnings and ends*—School schedules are periodic. At the transition between school years and marking periods, there are some information tasks that must take priority. For example, ensuring class rosters are

accurate, attendance can be recorded, and grades can be reported are among the tasks that must be reliably and quickly accomplished at these times. For this reason, ensuring the student information system is functional and accurate is the highest priority at those times. Because these are scheduled well in advance, many IT professionals will be sure to minimize scheduling other high-demand events to coincide with beginnings and endings of school years and marking periods.

Customer Service Skills

Regardless of the role they fill, 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 service 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 user 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.

Scheduling 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 examples 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 on 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. (This assumes, of course, that the students are allowed to carry their phones in school!)

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 courses necessitate the use of special software can reserve certain computer rooms where it is installed.

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 of these complications pose a serious impediment to sufficient access.

Network Security

All IT professionals are familiar with the steps they can take to maintain networks security, and they know addressing network security issues is an on-going part of their work. As new software is deployed, there are new threats to security and privacy. 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 is 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 known 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. Typically, IT managers provide a “guest SSID” that provides very limited service and others’ devices connect to that wireless service (Scarfone & Mell, 2008).

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; in some cases, the monitoring is automated and triggers are added to notify system administrators of anomalous patterns. 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 backup 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 “do not assign” list on the DHCP server which means it will not have an IP address, so it cannot connect to it.

Design Cycle

We know IT systems must be appropriately designed, properly configured, and reasonably implemented. These characteristics are not necessarily the same and can be contradictory.

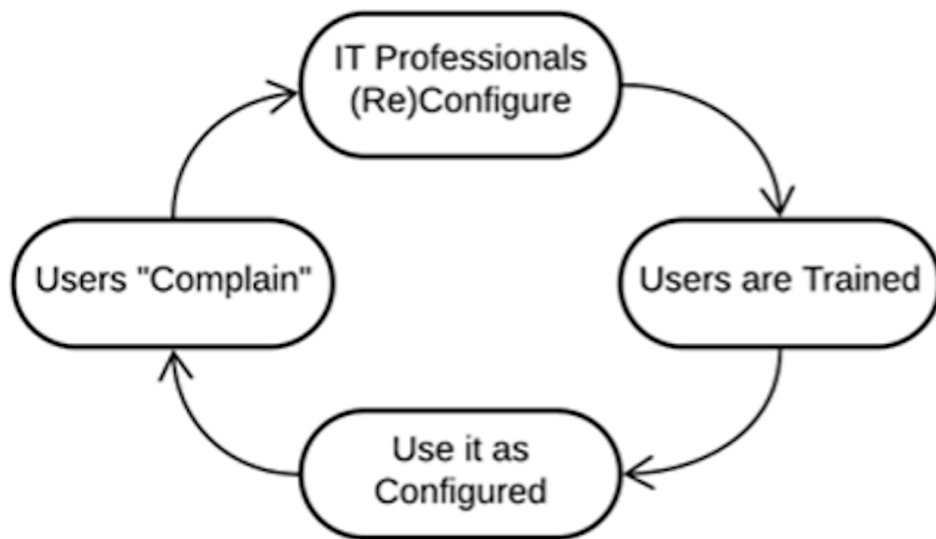
A fundamental aspect of managing school IT systems is designing them for the purpose of continuously improving them. In general, appropriate design must be the primary goal of the design, but proper configuration is also essential, and school administrators always have the ultimate decision-making authority. By following the design cycle, steering committees can design for improvement, and school administrators can decide which perspective should be given priority at any point in the design process.

The design cycle begins with technicians configuring systems according to their knowledge of proper configurations, limits of their skills, the extant infrastructure, budgets, time, and other locally relevant circumstances, especially their understanding of the appropriate design. Once the system is built, technicians must ensure teachers and others understand how to operate it, and they have an obligation to understand and follow those procedures. If teachers and students are using the system as designed by the technicians, but they find the design is not what they need, then they “complain.” The factors associated with technology acceptance—specifically ease of use and effectiveness, as more completely described in the chapter 'Theories and Educational Technology'—are used to frame the improvements that are needed, so they are not really complaints. If the school has a well-functioning steering committee, then they will meet to define the new

configuration that will ensure the new version of appropriate design is realized.

This design cycle may be used either formally or informally and different components of the total IT system in the school can be at different stages of the cycle at any moment. Further, each stage of the process may require multiple iterations before the process is sufficient for the next stage to begin. The degree to which a stage is completed before the next iteration begins appears to correlate with teachers' effort expectancy.

Figure 23
Design Cycle for Improving School IT



At different stages of the cycle, all stakeholders must defer to decisions made by different participants. Technicians make initial design decisions, so educators must defer to their expertise and use systems as the technicians design them to be used. When educators find aspects of the system that interfere with technology acceptance, then technicians must defer to educators' perceptions and change the system to

improve their acceptance. School administrators are hired to manage school operations and to ensure conditions are appropriate for teaching and learning. When progressing through this technology planning cycle, school administrators must recognize the stage and ensure the recommendations of the correct stakeholders are being implemented.

When the planning cycle is active and completed in a continuous manner, the practice is associated with improved perceptions of facilitating conditions. A principal captured the effect of focusing on technology acceptance during the planning cycle. “When we talk about technology at faculty meetings, I used to hear endless griping about how stuff was never fixed. The technicians stuck to their plans and were reluctant to modify things.” After introducing the design cycle and insisting “complaints” be expressed as those aspects of the system that made it hard to use or that interfered with teaching, the perceptions of the system seemed to change. He observed, “We have opened communication about the role of the system in our school and the conditions necessary for it to serve our purposes” (Ackerman, 2018).

Laws, Policies, Standards

Rules We Must Follow

There are several types of rules we are obligated to follow if we are going to work as professionals in schools. The authority for these rules varies, and some make sense to us while others do not. By understanding the nature of these rules, we better understand the rationale for following them.

Because of their experience as students, many adults believe they have a good sense of the nature of schools. They believe they know about the nature of teaching and learning, but many of those assumptions are grounded in the standard model of education, which we know only partially describe it. They believe they know about hierarchy and authority in schools, but as we know, there are many sources of authority. Many of the assumptions that adults have about school have been informed by a relatively small number of other adults. Much of their understanding about the hierarchy that exists in schools is grounded in their experience of interacting with a small number of adults. As students, we engage with only those adults who are in our classes and a few other situations. Students rarely see those adults who work in central offices or those who are associated with external organizations that affect what happens in schools.

This chapter is largely about how adults who students rarely see affect what happens in schools. These are called “rules we must follow,” because the IT professionals who do not follow them are likely to be removed from their positions. These rules are not necessarily evidence-driven in the same way that theory is. (This does not stop people from using the term “data-driven” to describe them. In reality, they are “interpretation-driven” as the data are selected to support the pre-made decision.) Many of these are political

decisions, but they are not presented as such. Almost every decision made in schools is framed as “what is best for children.”

It may seem unnecessary to state it, but schools are places where children are present. Lots of children. Children who reflect the social, racial, ethnic, and other characteristics of the local population. They are everywhere and they affect every decision that is made. Ostensibly, decisions are made to support student learning, but the reality of that goal is questionable. Consider, for example, the fact that there is ample evidence that high school-aged people can experience health benefits and improved learning if the school day starts in the late morning, but schools have been reluctant to update their schedules to align with this finding. Consider also, one very important function of school is providing reliable childcare for large parts of the population. While this cannot be minimized, it seems contrary to the goals of teaching the academic curriculum which is typically ascribed to schools. One of the reasons the decisions made in school may be contrary to “what is good for students” is they are multidimensional; schools fulfill several purposes and different individuals and groups exert influence on decisions.

Schools are political organizations. They are funded by taxes levied by state and local governments in the United States, and citizens serve on school boards that govern local schools. Because the officials who fund and govern schools are elected, their selection is a political process. This opens the process of school governance to partisan politics, and participants in such decision-making are not bound to use evidence and reason in the same manner as scientists and scholars; so, any decision can be justified.

Schools are also regulated organizations. Governmental agencies, which take their directions largely from legislation, define the policies local school boards are expected to adopt, and they provide guidance on the contents of those policies. They also approve the qualifications necessary to be a licensed teacher or administrator and approve teacher education programs offered by college and universities. In the United States, the federal government did not exert much influence on education until the Department of Education was

founded in October 1979, and since then it has sought to influence decisions and priorities through grants and other programs, but most school regulations and decisions are made by state and local governmental agencies.

Schools are also hierarchical and authoritative organizations. Teachers have some authority over students, and administrators have authority over students and teachers. This authority is not absolute, of course, but it does influence decisions that are made and actions that are taken. The hierarchical authority in school is grounded in age (teachers are adults and the students are children), but also from the position one holds (administrators have more responsibility than teachers) as well as expertise (teachers are experts compared to students, and ostensibly administrators have greater expertise than teachers). As a result, even in classrooms in which the students are adults, there exists a hierarchical and authoritative relationship between students and teachers.

Further, schools are organizations that rely on diverse expertise, and this is especially true in relation to information technology. Early in the history of desktop computing in schools when classroom computing comprised small numbers of computers that were not connected to networks, it was common to find tech-savvy teachers who supported and managed the devices that were in their classrooms. Today, few educators have the training and experience necessary to configure and manage the enterprise and business class IT systems that are needed for teaching and learning and school operations. As a result, we do find skilled IT professionals who work in almost every school.

In most jurisdictions, the executive leaders who are responsible for all school operations, including the IT, are licensed educators who began their careers as teachers. Their experience teaching with technology was probably years ago. As a result, many initiatives are proposed, and even undertaken, without complete consideration of the technology implications. The opposite is true as well; IT professionals often undertake technology initiatives without complete consideration of the educational implications.

Efficacious Educational Technology

Because schools are multidimensional, and many individuals and groups influence the decisions that are made, no person who works in a school has exclusive authority to make decisions about their work. In this, school employees and leaders are like other regulated and board-governed organizations; our decisions may be countermanded by others.

Table 23
Comparing the Rules We Follow in Schools

Category	Who Creates It	Purpose	How It Shows Up in Schools
Laws	National or state legislatures	Establish legal requirements and rights	Privacy protections, accessibility mandates, data-handling obligations
Regulations	Federal or state agencies	Translate laws into actionable requirements	Rules for data security, reporting, accessibility
Policies	School boards, districts, institutions	Define expectations for staff and students	Acceptable use policies, device rules, software approval processes
Standards	Professional bodies, industry groups, agencies	Ensure consistency, interoperability, and quality	Accessibility standards, cybersecurity frameworks, data format standards
Procedures	District departments, IT teams, administrators	Ensure consistent execution of policies and standards	How to onboard a new device, reset passwords, approve new apps

In many other types of organizations, the authority on which decisions and judgments are grounded is the financial success of the organization. In schools, this measure of success is absent. Various factors emerging from the political, regulatory, and authoritative natures of schooling contribute to the decisions made and actions taken (even if they seem unreasonable to those responsible for implementing them). Students are often unaware of these competing influences on the schools they attend. This makes schools as workplaces for adults very different from learning places for students, and some adults find they cannot work in schools.

For educational technology leaders, many potential decisions related to tools, configurations, or how decisions are deployed are influenced by laws, regulations, and policies. When technology is efficaciously managed in schools, collaboration between school leaders, who are primarily responsible for implementation, and IT leaders will ensure decisions are aligned with these rules from the beginning of the process, so no plans are abandoned because they do not follow them.

In this chapter, we discuss several types of rules we follow. Laws, regulations, policies, procedures, and standards are all designed to accomplish different things.

Laws

In the United States, laws are generally mandated by national, state, or local legislative groups. School leaders are obligated to comply with laws, just as people in all industries must comply with the relevant laws for their industries. These laws are not abstract constraints; they are the structures that determine how schools are to interact with individuals and how the school will operate.

National laws in the United States tend to focus on foundational rules that determine how schools operate. Of particular interest to IT professionals are laws related to privacy, civil rights, accessibility, and data protection. As

classrooms become increasingly connected and data driven, legal frameworks provide the guardrails that protect students, guide institutions, and ensure that innovation does not outpace responsibility.

Digital tools offer unprecedented access to information, personalized learning pathways, and powerful analytics, but they also introduce risks related to privacy, equity, and security. Legal frameworks help schools navigate these tensions by establishing expectations for transparency, consent, data stewardship, and accountability. In doing so, they create a foundation of trust that allows technology to support learning rather than undermine it. The rapid evolution of artificial intelligence, cloud computing, and networked devices has intensified the need for clear legal guidance. Schools now manage vast ecosystems of platforms and services, each with its own data flows and potential vulnerabilities. Laws provide a common language for evaluating these systems, ensuring that decisions about procurement, implementation, and oversight are grounded in shared principles rather than ad hoc judgment. This legal grounding is essential for maintaining consistency across classrooms, districts, and states.

In other sections of the book, I described the *Children's Internet Protection Act*, the *Children's Online Privacy Protection Act*, and the *Federal Educational Rights and Privacy Act* which are related to the unique users and data collection that characterize schools. There are other examples of laws that continue to be in effect as they have not been repealed:

- *Elementary and Secondary Education Act*—This law first passed in 1965 and has been reauthorized in the decades since.
- *Every Student Succeeds Act (ESSA)*—This law was first passed in 2015 and has been reauthorized in the years since.
- *Individuals with Disabilities Education Act*—IDEA ensures students have access to the assistive and other technologies necessary for

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them to receive a free and appropriate education in the United States.

In the United States, individual states hold the primary authority over education, so most operational rules come from state legislatures. Because each state sets its own rules, the legal landscape for educational technology can vary significantly across the country.

Common state laws concerning education include:

- *Curriculum laws*—Some states have laws related to what gets taught in classes; these statutes also include rules regarding accountability, measuring the degree to which the curriculum has been implemented.
- *Funding*—In the United States, most state governments have laws that control how schools receive funding and how they spend their money.
- *Teacher certification laws*—Teachers and school administrators hold licenses for the specific state in which they work. State laws affect who gets licensed as well as the laws affecting the colleges and universities that train teachers.
- *Safety*—School security and safety are also affected by state law. In many areas, those individuals who are going to work in school, and even volunteer in some cases, must undergo a background check and be fingerprinted. This is an example of a law related to school security.
- *Technology use*—Increasingly, states are passing laws related to technology use; For example, state laws are restricting the use of mobile phones in schools.

Local education laws typically focus on addressing community-specific needs, values, and resources. In many cases, local educational laws are quite detailed and generally referred to as policies rather than laws.

Ultimately, the legal landscape of educational technology is not static but continually adapting to new tools, new risks, and new expectations. By understanding the principles that underpin these laws, educators, leaders, and IT professionals can engage more confidently with emerging technologies and anticipate the challenges ahead.

Regulations

Regulations form the practical, operational layer of governance that turns broad legal principles into actionable expectations for schools. While laws establish the “what,” regulations define the “how,” translating legislative intent into detailed rules that educators, technology leaders, and vendors must follow. Regulations are enforced by agencies which are typically part of the executive branch of state governments. In the realm of educational technology, these regulations determine how digital tools are implemented, how data is handled, and how systems must function to remain compliant. They also provide mechanisms for oversight, enforcement, and accountability when systems fail or are misused.

Unlike laws, which tend to be stable and slow to change, regulations evolve more rapidly in response to emerging technologies and shifting educational needs. As schools adopt cloud platforms, artificial intelligence, and data-rich learning systems, regulatory agencies issue guidance, technical standards, and compliance requirements to ensure these tools are used safely and responsibly. This dynamic nature makes regulations especially important for technology leaders, who must stay attentive to updates that may affect procurement, data governance, or instructional practices.

An example of the differences between laws and regulations is illustrated by the process for licensing in Vermont. Vermont law specifies the

Vermont Standards Board for Professional Educators as the organization legally responsible for licensing educators in the state of Vermont. The VSBPS establishes regulations regarding educator preparation, licensing requirements, endorsement areas, disciplinary actions, and other actions related to licensing. One of the reasons regulatory agencies are given authority to act for the state to grant licenses is the people in that agency are professionals in the field and unlikely to be affected by political arguments.

An example of regulations relevant to many educational technologies is Erate. Erate refers to funds that are administered by the Universal Service Administrative Company under the direction of the Federal Communications Commission to disburse Universal Service Fund collected from a charge added to telephone customers' bills. These funds are used to provide high-speed internet connection and networking equipment to ensure equitable access to this technology for students in all schools. School and IT leaders are not required to participate in the regulations related to Erate, but that means they do not have the option to access those funds.

Ultimately, regulations are a living framework that adapts alongside the technologies shaping modern learning. They ensure that as tools become more powerful, the systems governing them become more robust. By grounding innovation in clear expectations and protections, regulations help schools navigate the complexities of digital transformation with confidence.

Policies

While laws and regulations are rules all schools must follow, policies are rules that only affect operations in a single school or district. Policies are adopted by the board of education as part of its duties for governance. Once adopted, policies determine the appropriate actions of school employees and, in some cases, students. Many policies are adopted to align with laws and regulations, and they serve to protect the school from the actions of employees that are illegal. If an employee does something that violates a policy, they can

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be dismissed. Other policies are aligned with the principles of school operation as defined by the board. Examples of policies include:

- *Attendance policies*—Define what it means to attend the school, what counts as excused absences, and steps for addressing truant students.
- *Bullying, harassment, and hazing policies*—Define these actions, and steps that are to be taken when events are documented.
- *Sexual harassment policies*—Define what constitutes sexual harassment and steps to be taken when it is documented.

While policies vary based on the state laws and regulations and on the priorities of the local community, examples of policies of interest to IT professionals are:

- *Acceptable use of technology policies (AUPs)*—These rules describe what it is appropriate for students, teachers, and staff to do with the IT systems owned by the school. These typically address harassment and bullying as well as the use of school-owned devices for personal purposes.
- *Device programs*—As one-to-one initiatives became common, policies regarding the conditions under which technology could be removed from campus became equally common. While these are intended to protect the devices owned by the school, different rules for different individuals can make digital divides more common if the devices are to be used to complete assignments away from school.
- *Classroom technology integration*—While curriculum decisions are largely determined by individual educators, it is not unusual

for there to be specific policies related to technology integration. These tend to restrict the use of cloud systems, for example teachers may not be allowed to use a learning management system other than the one provided by the school. Other integration policies may ensure access to certain experiences.

- *Software adoption*—Software can represent a very significant expense for schools. Especially when including training, the total cost of ownership of software can be very high. To ensure new software is compatible with existing systems and minimize other potential disruptions, many schools have formal procedures in place to adopt software.
- *Data-handling policies*—These policies will ensure all data is handled according to FERPA and any other laws related to encryption or other strategies to ensure privacy.

Local policies are the most practical and detailed, shaping what teachers and students experience in classrooms and how technology is used by other employees. Among many professionals, there is sometimes confusion regarding policy and procedures. Policy is a part of governance. It must be agreed to by those who are responsible for governing an organization, such as a board of education. When deciding reasonable implementation, school administrators look at policy first. Procedures are the rules we decide to follow to keep the organization running smoothly. They can be adopted and abandoned at the will of the leaders, and we only really get into trouble when procedures violate policy. School leaders decide which procedures the school will follow, but the rationale for their decisions is grounded in their priorities, not in the school's policies.

Budgets & Procurement

A key aspect of reasonable implementation of educational technology is dealing with budgets. As public institutions, schools are compelled to follow the laws and regulations related to how money is spent. If the school is not public, then the governance system for the school likely has some policies regarding how money can be spent.

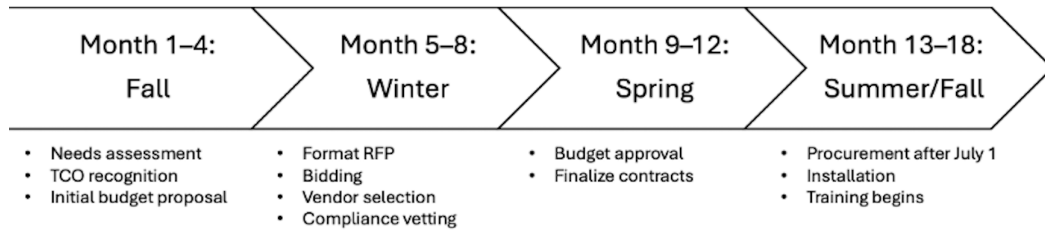
While they are not immediately responsible for the financial aspects of managing school finances*, as that work is done by the accounting staff, school IT leaders are responsible for both developing budgets and overseeing expenditures. In collaboration with other school leaders, school IT professionals work to identify technology needs, formulate system requirements often in collaboration with outside vendors, and develop budget proposals. Those proposals are incorporated into the other school needs, and those are approved (or not approved) based on the laws and regulations that govern the school as well as the local priorities established by the governance structures.

Once a budget has been approved, then the IT leaders are responsible for making purchases. This includes obtaining quotes from vendors and placing the orders. When making IT purchases, the devices that were used to develop the budget are often not available when the purchases are made. A common timeline in school budgeting is to begin developing the budget in the middle of the fall, having it approved in the spring, then taking effect on July 1. It is not unusual for the budget process to have begun 18 months before the fiscal year ends in many schools.

Regulations and policies may mandate that large projects—where 'large' is determined by financial cost—cannot simply be awarded to vendors without a bidding process. Such projects must be awarded based on a bidding process that follows announced procedures to ensure interested and capable vendors have the chance to prepare bids for consideration. Ensuring such steps are followed requires IT leaders to collaborate with the other school staff to follow regulations and policies.

Figure 24

The 18-month Budget & Procurement Lifecycle Common in Schools



School IT leaders also participate in the development of grant proposals. Grants can come from many sources, and they can be used for various purposes. When a school is awarded a grant, for IT or for any other purpose, they participate in a common process.

- *The application*—The grant funder will announce the grant program including the intended audience and purpose, maximum award, and application process. Once the school leaders are sure they are eligible and the need is one they have, they complete the application process. IT professionals are often involved with ensuring the IT in any grant application can be integrated into the existing TCO structure of the school.
- *Administration*—Once a grant is awarded, the school follows the rules of the award to ensure they comply with the expectations of the award. The application process typically specifies the items that grant funds can be used for and changes to those needs require an amendment to the application which must be approved by the grant funder.
- *Evaluation*—Grant funds must typically be spent in a limited time. Once the grant ends, awardees are typically obligated to report on how the grants affected their operations. This may include self-reported data, or

it may include participation with other vendors who are contracted by the grant funder to evaluate it.

Human Resources

Human resources professionals ensure their organization complies with the laws and regulations related to employment that affect their region. In many areas, these laws and regulations are supplemented by the master contracts that are negotiated between the unions and the school boards.

The term “onboarding” 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 onboarding procedures. The details of the school IT systems that must be the focus of the onboarding trainings have been described previously, and comprehensive onboarding training decreases the need for 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 owns 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 they created. Educators are content to avoid conflict by avoiding selling 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.

Standards

"Standard" is a term that has multiple meanings both in education and outside of education. It can mean "of high quality" as in "this project has been completed to a high standard." It can also mean "all have the same" as in "standardized tests" in which everyone takes the same test. Further it can be "a

collection of practices” which everyone should follow. In this section, I am referring to standard collection of practices. Of course, when we do follow these practices, which are generally the same for all industries, we align our work with that definition, and our systems are built to a high quality when we follow them.

Standards provide the shared language that allows educational technology systems to function reliably, securely, and consistently across classrooms, schools, and districts. While laws and regulations establish what schools must do, standards describe how to do it in a way that is technically sound and widely interoperable. They translate broad expectations into concrete specifications—covering everything from network performance to data formats to accessibility requirements. In a field where tools evolve rapidly, standards create stability and predictability.

Learning management systems, student information systems, assessment platforms, and classroom devices all rely on common protocols to exchange data accurately and securely. Without these shared specifications, schools would face constant compatibility issues, fragmented workflows, and increased security risks. Standards also support equity and accessibility by defining minimum expectations for usability, device compatibility, and inclusive design. When digital tools follow recognized accessibility and interoperability standards, students with diverse needs can participate more fully in learning. This consistency is especially important as schools adopt AI-enhanced tools, cloud platforms, and mobile devices that must work for all learners regardless of ability or context.

For technology leaders, understanding standards is essential for making informed decisions about procurement, system integration, and long-term planning. Standards help districts evaluate whether a product will scale, whether it will integrate with existing systems, and whether it meets security and privacy expectations. They also guide conversations with vendors, ensuring that schools adopt tools that align with best practices rather than proprietary or incompatible solutions.

Curriculum Standards

As described in chapters on appropriate design, there are many subject areas for which curriculum standards have been written. As with all standards, these are recommendations for acceptable practice, and regulations are often grounded in regional curriculum standards. In those situations, there is close alignment between the regulations and the standards.

Curriculum standards are documents that are under constant review. For IT professionals, what comprises “technology aligned with educational standards” during one year may differ from the expectations the next year. This can be further complicated by the fact that different standards review processes are at different stages for different subjects.

Technology Standards

A number of professional organizations for technology professionals have also created standards for how IT should be configured to remain reliable, robust, and secure. Technology standards are defined for all organizations; schools should follow these just as any other organization should follow them. In some cases, for example the standards for networking and WiFi, the devices we purchase to maintain school network infrastructure have been built to align with the standards. Such standards also affect data systems; for example, student information systems and learning management systems are created to align with standards to ensure interoperability.

Examples of standards that address the design and delivery of IT systems in schools are:

- *NIST Cybersecurity Framework (CSF)*—A structured set of cybersecurity best practices that helps organizations identify, protect, detect, respond to, and recover from digital threats.

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- *NIST SP 800-53*—NIST SP 800-53—A comprehensive catalog of security and privacy controls for information systems and organizations to protect against cyber threats and operational risks.
- *1EdTech (IMS Global) interoperability standards*—Interoperability specifications that ensure learning tools, platforms, and data systems can exchange information reliably and securely.
- *WCAG 2.1 accessibility standards*—Accessibility guidelines that define how to make digital content usable for people with disabilities.
- *Section 508 accessibility requirements*—Federal accessibility requirements ensuring that digital tools and content are accessible to all users, including those with disabilities.
- *IEEE 802.x Standards*—Networking standards that define how wired and wireless communication (such as Ethernet and Wi Fi) operates.
- *CoSN Trusted Learning Environment (TLE) framework*—A framework that guides school districts in implementing strong student data privacy practices.

Key Takeaways

This book is about schools; the technology they need; the people who use, operate, and lead the IT; and the guidance they all have so it functions as it should. Folks who were looking for specifics of how to be an educational technologist are likely to have been disappointed. Details of what to do in any situation vary, so we cannot always predict what the best course of action is. I have sought to outline principles of how to be an educational technologist and these will help everyone do this work well.

Solve Problems. No, Really Solve Them

When I was deciding how to end this book, I observed an interaction between a school technologist and the staff at a school. In the school, the phones are used to give announcements (a very common solution). There are areas of the school where announcements cannot be heard, so the IT department was planning to install additional speakers so the announcements could be heard throughout the building.

The technologist asked the principal's secretary for a list of spaces where they needed speakers. "We don't want to be making any decisions here," they said, "if it doesn't work, we want to be able to say 'we put them where you told us to' so it is not our fault."

I understand the rationale for making the request, but it is a sure sign the IT department is dysfunctional. If they really wanted to be sure the money (and their time) was going to be well spent, they would arrange to take the time to ensure the speakers were placed where they needed to be; they would be no one to blame as the problem would be solved.

It takes time to ensure such steps are taken, but at least the problem is solved and the IT department need not take the time to fix it again later. I argue (and my experience demonstrates) that taking the time to actually solve problems and to be friendly and collegial when you do is the most important

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thing that leads to success for any individual who works in educational technology.

Be Aware of the Lanes, and Stay in Yours

Efficacious Educational Technology requires collaboration, as no one individual has the expertise to solve all the problems we encounter in the field. We have seen Appropriate Design put teaching and learning at the center of many school IT decisions, and educators must take the lead in deciding what to do with technology in schools.

We know computer systems and the data stored on them must be secure and reliable. That is accomplished through Proper Configuration. The configurations must be managed to stay secure and reliable as progress is made to fulfill the designs necessary according to educators.

We know school leaders take steps to ensure schools, including the technology that is basic school infrastructure, functions as it should. As IT professionals, we must recognize there are reasons (usually) for why leaders make decisions. In my experience, it is acceptable to ask about leaders' (often wacky) decisions, but their decisions are their decisions. You can help them make good ones (from your perspective), but they make them and are ultimately responsible for them.

The Task Never Ends

When I originally started writing this version of the book, I had many more chapters outlined. I opted to not include them, but I add a list of topics that any school IT professional is likely to want to be able to navigate. Consider this a “to do” list of things to investigate as you work in educational technology:

- *Google Workspace for Education*—For more than 20 years, Google has dominated school IT. It started with Gmail and has expanded into most every aspect of software, and of course hardware through Chromebooks. If you want to work in school IT, you need to know how to manage Google Workspace.

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- *Generative AI*—It was very easy to decide to drop my chapter on artificial intelligence from this book as I wrote the outline for the chapter and realized it was made obsolete within a month. AI is here; it can be scary if you only listen to the news reports and do not spend time with it. Learn to use it, but do not allow it to speak, write, or think for you. (Yes, I did use AI in writing this book, but I used it as a copy editor. I realized it is good at finding errors, but terrible at communicating what I wanted to communicate in writing.)
- *Ethics*—Technology is a variable in society today. What represents a sound ethical decision today may be unethical tomorrow. Recognize ethics as something within your domain as an educational technologist and recognize as well that the factors that determine ethics change.
- *Security*—Originally, I had a chapter on security, but the chapter was going to be an entire book. Privacy and security are essential to design, configuration, and implementation of any IT system.
- *Accessibility*—One of the great things about digital information is that we can take steps to ensure it can be used by anyone. We must take steps to ensure that information can be used by anyone. This is among the most important things we do as technology leaders in schools. Be sure folks can easily make their course materials available to everyone.

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