Lecture Notes in Educational Technology

Ronghuai Huang
Kinshuk
Jon K. Price *Editors*

ICT in Education in Global Context

Comparative Reports of Innovations in K-12 Education

Springer

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Foreword

Nelson Mandela said, "Education is the most powerful weapon which you can use to change the world." Whether educational researcher or teacher, most would agree about the importance of education, even as we are challenged with the creation of systems and environments that promote learning as the foundation of education. In this volume, Professors Huang and Kinshuk, and Dr. Price bring together some of the leading global researchers and practitioners to share their work and experiences involving information communication technology (ICT) innovation in K-12 schools across diverse international settings.

This book is the result of a comparison study of ICT across global K-12 settings through a partnership of Intel™ and the China Ministry of Education (MOE), with the intent to capture the current advances and emerging trends of digital technologies for learning and education. Stakeholders have long recognized ICT as a key enabler of innovation and creativity in K-12 schools and in education, in general. However, there is widespread agreement that the widespread, sustained positive impacts of ICT have not met the expectations of stakeholders. Recent decades have seen dramatic increases in ICT infrastructure and access to educational technologies for learning in most countries. Advances in the area of learning sciences have us on the verge of a research-based theory of how people learn. The research base for the effective implementation of ICT for student learning and for teacher professional development has expanded greatly, as well. Yet, there remains a substantial gap between the research findings and their effective application in K-12 learning environments. This gap is exacerbated by the rapid acceleration of technology advancements which challenge each of us in our workplace, our homes, and in our social and family networks, but addressing the gap for K-12 education is a primary target of this volume.

The first of four parts of this book includes chapters describing innovative instructional models which have been implemented in globally diverse K-12 settings. Knowledge building, design thinking, and capacity building are foundational to these innovative models. The second part includes chapters focused on the design of educational environments that promote learning for K-12 children in a digital age.

Instructional design fidelity, informal learning experiences, and ICT infrastructure and access are discussed with recommendations for stakeholders. The third part includes chapters that describe development models for K-12 ICT classrooms. Authors of this part highlight digital learning resources in China, implementation efforts, digital content, and blended learning. The fourth part includes chapters devoted to supporting sustainable e-learning design and development including leadership for ICT implementation in diverse, international settings. These chapters discuss a broad range of issues associated with moving from theory to research to practice including data driven decision making, technology integration, systems and systemic change, school leadership and policy, teacher professional development, STEM education, 3D technologies, and education transformation. In the composite, this book shares the practitioner and ICT researcher perspectives of nearly 30 internationally recognized innovators who believe in the power of ICT to create effective, engaging, satisfying, student-centered learning environments.

I am thrilled to know you share my interest in the potential for ICT to have a positive impact on supporting, improving, and enhancing learning and teaching! As a policy maker, practitioner, researcher, or instructional designer, the chapters in this book offer significant suggestions and recommendations to promote effective uses and integration of ICT in K-12 educational settings. The world of the K-12 learner today is fully contextualized by advanced learning technologies with access to global connections not possible for previous generations: cloud technologies, mobile applications, online learning, wearable technologies, "smart" technologies, manufacturing and fabricating (3D) technologies, to name a few, offer tremendous opportunities to transform K-12 learning environments, especially when implemented with strong research grounded in exemplar, contemporary global practice. I close my welcome to this volume with a quote from Jean Piaget, "The principal goal of education in the schools should be creating men and women who are capable of doing new things, not simply repeating what other generations have done; men and women who are creative, inventive and discoverers, who can be critical and verify, and not accept, everything they are offered." This book is an exciting read for those of us who agree with that principal goal and who are marveling at the rapid advances in technology that stand to revolutionize how children learn, play, communicate, collaborate, and socialize… enjoy!

Kay A. Persichitte
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Preface

During the past years, the increased interest in applying digital technologies aiming to improve learning and teaching has led to significant growth of research and practice of ICT in education. Educational stakeholders recognize the role of ICT as a key enabler of innovation and creativity in K-12 schools and for learning in general. They also highlight that, although the infrastructure to promote ICT use for learning and a sound research base to guide the process are widely available, the full potential of ICT is not being grasped in formal education settings. To this end, this book aims to capture the differences of ICT-based innovations for promoting the effective application of ICT in education by a number of invited chapters in key research areas.

The book is structured into five parts.

Part I: Patterns of Innovation for Instructional Models

The first part includes two chapters. Marlene Scardamalia and Carl Bereiter discuss the meaning of knowledge building/knowledge creation and importance of transformation from teaching for understanding to knowledge building. They argued that the goal of spanning Knowledge Building theory, pedagogy, and technology was to recreate schools as knowledge creating organizations—a formidable educational challenge requiring a shift in the modes of thought that since ancient times have characterized education. Jinbao Zhang and Linglin Meng discuss the ICT supported instructional innovative practice and diffusion mechanism of K-12 in China.

Part II: Methods to Design Learning

The second part consists of three chapters. Michael Spector discusses some issues for ICT supported instructional design by considering the emerging technologies and challenges for effective design of instruction. The chapter also discusses how to prepare educational technologists and the logic models to advance research, design and practice. Chee-Kit Looi, Daner Sun, and Wenting Xie present the importance of informal learning, considering the concept of seamless learning. Some major concepts were discussed and methods were provided for integrating informal learning into formal learning in this chapter. Di Wu, Xiaorong Yu, and Jingyang Rao compare the differences of ICT infrastructure construction status in China and the United States from broadband access, classroom environment and popularity of terminal equipment. The authors also summarize the experience for infrastructure construction of ICT in education from three aspects.

Part III: Development Model of Digital Learning Resources

The third part consists of two chapters. Liang Yu, Chuqian Sheng, and Di Wu introduce the background, purpose and tasks included in the Teaching Site covered by the Digital Education Resources Project promoted by Ministry of Education in China to bridge the digital divide between the Western remote rural areas. Allison Powell's chapter provides a brief description of the field of K-12 online and blended learning in the United States, and an overview of the types of digital content available to K-12 students and teachers. She also discusses how content is developed along with the pros and cons of building content in contrast to purchasing content from a publisher.

Part IV: Promoting e-leadership Using ICT

The fourth part includes three chapters. Stylianos Sergis and Demetrios G. Sampson analyze the 70 existing school leadership decision support systems (SL-DSS), to gather insights that could drive future implementations of school leadership decision support systems towards providing more effective decision support affordances and tackling the identified shortcomings of existing systems. Glen Bull, Nigel Standish, Eric Johnson, and Hossein Haj-Hariri introduce the successful use of digital manufacturing in a Lab School in the US, and point out that central coordination and planning can facilitate effective use of digital manufacturing technology in schools. Martina A. Roth and Jon K. Price introduce the Intel Education Transformation Model, and discuss the effectiveness and impact of the Intel Teach

Leadership Forums in informing and supporting school leaders, such as increased support through funding, time release, priority status, interest, and involvement.

Part V: Enhancing Teacher Development Using ICT

The fifth part consists of three chapters. Daniel Mourlam and Mary Herring review the integration of ICT through the development of pre-service teacher Technological, Pedagogical, Content Knowledge (TPACK), as well as how the Intel Teach Elements (Elements) have been used to develop teacher knowledge of pedagogy and technologies. David A. Slykhuis and John K. Lee explore the application of TPACK and 21st Century Learning Design (21CLD) which are the two conceptual frameworks form the cornerstone of Technology Enriched Instruction (TEI) professional development workshop to promote the effective use of technology in the classroom. Punya Mishra, Danah Henriksen, Liz Owens Boltz, and Carmen Richardson develop a definition of e-leadership that extends from the business sector to encompass educational contexts. They used the Replacement, Amplification, and Transformation (RAT) framework to explain the varying degrees to which ICT has been used in business and education and relate this model to the research in e-leadership and teacher development.

We hope this compilation will benefit learners, educators, scholars, and trainers by providing them with insight into innovative K-12 school strategies. We would like to extend our gratitude to all those who contributed material, provided support, collaborative discussions, review, commentary, and assistance in the editing, proofreading, and development of this text.

Ronghuai Huang
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Contents

Part I
Patterns of Innovation for Instruction Model

Chapter 1
Creating, Crisscrossing, and Rising Above Idea Landscapes

Marlene Scardamalia and Carl Bereiter

Abstract Knowledge building/knowledge creation involves exploring idea landscapes, crisscrossing them in every direction to learn one's way around. Through pursuit of multiple and intersecting rather than prescribed paths, knowledge creators come to feel at home in a conceptual environment, able to pursue promising ideas, redirect work based on advances and failures, and adopt a "design thinking" mindset in which improving the conceptual environment is a realistic possibility. Such creative activity produces inventions, solutions to big societal problems, theories, cures, new business enterprises, and so on. It is the mainstay of success in what the OECD is terming an "innovation-driven" society. In contrast, schools tend to reduce the conceptual landscape through simplification of the range of ideas to be explored, paths to be pursued, and goals, leaving students to traverse a diminished space along fixed, common paths, with prescribed goals. School procedures leave little for design thinking to get hold of. The goal of Knowledge Building theory, pedagogy, and technology is to recreate schools as knowledge-creating organizations–a formidable educational challenge requiring a shift in the modes of thought that since ancient times have characterized education. In this chapter we consider some of what this radical departure entails in terms of classroom practice and technology supports.

Keywords Knowledge building · Knowledge creation · Idea landscapes · Metadiscourse · Design thinking · Knowledge building technology

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1.1 Introduction

Ludwig Wittgenstein in the preface to his *Philosophical Investigations* noted that the very nature of his investigations compelled "travel over a wide field of thought criss-cross in every direction." He said his thoughts were "soon crippled if I tried to force them on in any single direction against their natural inclination"; thus his work represented a "number of sketches of landscapes which were made in the course of these long and involved journeyings." Similar terms were used by Greeno (1991) in explaining something of a more everyday character, children's acquisition of number sense. He called it "situated knowing in a conceptual domain" and likened it to learning one's way around in a city. Such learning is achieved, not by following a few prescribed paths but by crisscrossing the domain (of whole numbers or of intersecting streets) by numerous paths, until one comes to feel at home in the environment, to never be lost, and to be able to get from any one place to another by reasonably efficient means.[1] Woodworth (1958) referred to "learning the environment," noting that if you force a rat along a fixed path it will learn that path but no other. Allow it to roam freely and it quickly learns the maze well enough that it can get to where it wants to go no matter where you place it. What sets humans apart is our ability to do this kind of "learning the environment" in nonphysical environments—in conceptual or idea domains.

1.2 Beyond Learning

Children learning their way around the domain of rational numbers are learning to deal with something that already exists. Wittgenstein, however, in crisscrossing the landscape of familiar philosophical and everyday ideas, was aiming to add to, transform, and rise above what was already there. His project was a creative one, even though it had much in common with and was based on "learning one's way around." He was going beyond learning to what is now popularly called "knowledge creation" (Nonaka and Takeuchi 1995) or, in educational contexts, "knowledge building" (Bereiter and Scardamalia 2014; Scardamalia and Bereiter 1991). This is not learning with an added ingredient called "creativity." It is a creative activity in its own right. It is the kind of activity that produces inventions, solutions to big societal problems, theories, cures, new business enterprises, and so on. It is the mainstay of success in what the OECD is terming an "innovation-driven" society. Developing people able to carry on this kind of activity is a new imperative for education.

[1]At a higher educational level, Spiro and colleagues (1987, 1990) use Wittgenstein's "criss-crossed landscape" metaphor to characterize challenges for university-level case-based work that aims to extend these cases so that they mirror real world complexity.

Going beyond learning to knowledge creation/knowledge building is not an additive process. It involves adopting a different mindset, a different mode of thinking: what is now coming to be called "design thinking" (Brown 2009; Martin 2009). Design thinking takes the kind of thinking professional designers do and extends it to other contexts. Design thinkers work with ill-defined problems, sometimes referred to as "wicked" problems (Rittel and Webber 1973). The problems are open to different definitions and to tentative solution paths of unknown destination; as work proceeds the nature of the problem changes, predetermined pathways will not suffice. Progress depends on pursuing promising ideas and redirecting work based on advances and failures.

The relation between learning and design thinking is a fluid one. Designers need to know their domains, and this involves the crisscrossing by multiple pathways that enables them to know their way around in the idea landscape. But they should not let habit take over and thinking follow only well-worn paths. The surest protection against this is to maintain a design mindset throughout—to always be looking out for a better path, a better way of viewing the landscape, to allowing—as Wittgenstein did—the ideas to find their own paths rather than have directions forced upon them.

A design mindset and a willingness to tackle "wicked" problems encounter an unintended sort of opposition in schools. For reasons that are well justified from a practical standpoint, there is a strong tendency in schools to reduce things to fixed procedures. Even problem solving itself is liable to be reduced to a specified set of steps. Furthermore, much of the teacher's art lies in simplifying content so that it can be grasped by all the students with varying levels of background knowledge. Reduction to procedures and simplification of content together mean that the students are traversing a diminished conceptual landscape by fixed paths—the very opposite of what Wittgenstein described and what "learning the environment" entails. Routinized investigation of diminished domains means there is little for design thinking to get hold of.

There is an important kind of thinking being widely promoted in contemporary pedagogy. It is the kind of thinking involved in argumentation (Andriessen et al. 2003). We call this mode of thinking "justification mode."[2] It is concerned with evaluating, defending, and refuting knowledge claims (Driver et al. 2000). It is a different mode from the design mode of thinking, out of which novel knowledge claims arise. Bringing design thinking into mainline work with curriculum content is thus a radical departure from both the routinized procedures of "knowledge

[2]In an earlier formulation (Bereiter and Scardamalia 2003), we used the terms "belief mode" and "design mode," and these terms have appeared in many of our writings and presentations since. However, we found that educators tend to equate belief mode with accepting and transmitting beliefs based on faith or authority, so that by implication design mode became equated with reliance on evidence. This totally misses the point of the distinction and assimilates it into a conventional good–bad polarization that is crippling to educational thought. Hopefully, replacing "belief" with "justification" gets rid of the false polarity and allows educators to see the virtues of both modes and their interdependence.

transmission" and the "justification mode" thinking that characterizes most of what is currently promoted as disciplinary thought.

Justification mode and design mode are both vitally important and found in all organizations. Any new idea needs justification before it can be rationally adopted or approved for further investment. But whereas an innovative organization might show a ratio of 90 % design thinking to 10 % justification, schools are more likely to show the reverse—or, in the case of core disciplinary subject matter, a ratio of 100 % justification to zero percent design. In education settings, with their emphasis on getting ideas right, justification deserves a substantial place in students' thinking, but we would argue that for schools attuned to the knowledge age, a design mindset should be all-pervasive and productive design thinking ought to occupy more than half of activity in disciplinary courses. Does this mean less time for learning? No. Design thinking inevitably leads to learning related to whatever is being designed. If students are designing ideas in a conceptual domain (that is, producing explanations, theories, interpretations, and the like) then they inevitably learn domain content. There is no evidence of disadvantage in learning content knowledge, compared to more conventional approaches, and clear advantage in other socio-cognitive outcomes (e.g., Chuy et al. 2010; Zhang et al. 2009).

The societal need for design thinkers is evident both when the goal is innovation and when it is survival (Homer-Dixon 2000). A conclusion pointed to by the preceding discussion is that producing design thinkers is a very formidable educational challenge, requiring a shift in the modes of thought that since ancient times have characterized education. It is not enough—may even be of no effect—to promote creativity as a character trait or skill. Design thinking needs to pervade the school experience, and this means bringing it into the heart of the curriculum, not leaving it as an occasional or extra-curricular activity. In the remainder of this chapter we consider what such a radical departure entails in terms of classroom practice and what supports technology may provide for it.

1.3 Student Responsibility for Idea Improvement

It is now generally recognized that students are not blank slates when they enter a new area of subject matter. They already have beliefs and dispositions to think in certain ways about the ideas presented. Sometimes these prior beliefs and dispositions stand in the way of grasping and internalizing what is taught; a whole field of research has grown up around issues of conceptual change (e.g., Vosniadou 2013). More generally, the expectation is that in all areas students will leave school with better ideas than they brought in with them. But the responsibility for bringing about this idea improvement is mainly assigned to the teacher, with the student expected to cooperate. This means that the teacher is the one who does whatever design thinking goes into idea improvement. That generalization seems to hold not only for "instructivist" approaches, where the teacher's responsibility is taken for granted, but also for most "constructivist" approaches. In these approaches, variously termed "inquiry" or "problem-based" or "project-based" learning, idea development is viewed as coming about through students' own constructive thought, but *responsibility* for making it happen remains with the teacher. Yet idea improvement is a driving force in design thinking of all kinds. If students are to develop into design thinkers who go beyond received notions, school ought to be a place where they gradually take on the responsibility for idea improvement in their community.

Knowledge Building[3] is an educational approach focused on collective student responsibility for knowledge advancement and idea improvement (Scardamalia 2002; Scardamalia and Bereiter 2003, 2014a). Working to improve one's ideas about the world is a challenge to both intellect and character. In the normal course of life, idea improvement is failure-driven; it takes place when something malfunctions, falls short of its goal, or upsets our expectations. Scientific beliefs, social beliefs, moral beliefs, and so on are seldom perceived as having failed, and so the basic motivation for idea improvement is weak. It needs support. Teachers can provide support, but need to resist taking on the responsibility for idea improvement; instead, their task is to help the students take on such responsibility. The other major kind of support is peer support. That is why Knowledge Building emphasizes *collective* responsibility and establishing communities in which idea improvement becomes the norm—a norm that both students and teachers help in maintaining. The proposition that all ideas are improvable serves in Knowledge Building as a working assumption. It isn't always true. There are unimprovable ideas, sometimes because they are hopelessly imperfect, but more often because they are vacuous. But as a working assumption it not only gives students license to criticize received ideas (most thinking-oriented approaches do that) but it also conveys the challenge to produce a better idea and suggests that, rather than summarily rejecting a faulty idea, they should try to build on whatever merits the idea has and, like software designers, produce a new and improved version.

1.4 From Teaching for Understanding to Knowledge Building

"Teaching for Understanding" is a banner behind which march hundreds of thousands of reform-minded educators,[4] especially those with connections to the learning sciences or mathematics and science education. Besides being valued in its

[3] Because the term "knowledge building" now appears in many documents, often without definition, we use lower case with the generic term and capitalize Knowledge Building when referring to the approach originating in our laboratory and promoted by organizations such as Knowledge Building International.

[4] As of April, 2015, there were 264,000 Google references to this phrase. Figuring that there are 10 sympathizers for every web publisher, the estimate of hundreds of thousands might well be increased to millions.

own right (all the great philosophies and religions pursue it), understanding is also implicated in all sorts of other educational issues. Understanding aids memory and recall, enabling us to reconstruct knowledge we have partly forgotten. It plays an important role in transfer of learning to new situations (Bereiter 1995). It provides a basis for productive analogies and comparisons. And, in the form of "principled practical knowledge," it grows out of and enables the solution of design problems (Bereiter 2013).

No one, of course, is opposed to teaching for understanding, but the need to take it more seriously was brought home to educators by mounting evidence over the past 20 years of failures of students to learn with understanding. As we have said before, it appears that we are sending large numbers of students forth into the so-called Knowledge Age with pre-Newtonian physics, pre-Darwinian biology, and pre-Smithian economics. In recent decades, attention has become focused on the "big ideas" that underlie and give coherence to whole fields of study. Examples are the idea of force in Newtonian physics, natural selection in evolutionary theory, and market in economics. Without the understanding of these ideas, the study of their associated disciplines tends to be rote, regardless of teachers' efforts to enliven it with projects, experiments, problems, and debates.

Teaching for understanding and knowledge building are closely related, but not the same. There are other ways than knowledge building to teach for understanding; for example, lecture-demonstrations can be effective provided the students are actively trying to understand what is being taught. By the same token, knowledge building in education has purposes that extend beyond understanding—for instance, democratization of knowledge, idea diversity, and socializing students into a knowledge-creating culture (Scardamalia 2002). Solving authentic problems of understanding is a major concern of knowledge building across the whole educational spectrum. Consequently the widespread interest in teaching for understanding can serve as the entering wedge for bringing knowledge building into formal education. The point we want to argue in this chapter, however, is that design thinking constitutes a powerful way and probably the most powerful way to pursue understanding. The philosopher Karl Popper made this point in talking about understanding a theory:

> What I suggest is that we can grasp a theory only by trying to reinvent it or to reconstruct it, and by trying out, with the help of our imagination, all the consequences of the theory which seem to us to be interesting and important…. One could say that the process of understanding and the process of the actual production or discovery of… [theories, etc.] are very much alike. Both are making and matching processes. (Popper and Eccles 1977, p. 461)

Popper has here described what some educators would characterize as "active learning." However, it is a very distinctive (and uncommon) sort of activity that could better be characterized as constructing a theory that is heavily dependent on an existing theory. It is an effort that aspires earnestly to coherence with relevant facts—facts about the world and facts about the theory in question. It is design thinking enlisted in the service of achieving understanding, and it represents Knowledge Building in an exemplary form.

Both teachers and technology can help students accomplish high-level knowledge building of this kind. To do this teachers must believe that students can and should take the initiative in constructing a theory-like understanding of the world and in improving their own ideas. This will vault teachers beyond lecturing, Socratic questioning, guided discovery, and the many other common approaches to teaching for understanding.

1.5 Teachers Becoming Knowledge Creators

In order for teachers to help students become knowledge creators, they themselves need to have experience in knowledge creation. Ideally, a school faculty will function as a knowledge building community, working to advance the state of the art in teaching at both conceptual and practical levels. But at a minimum, preservice teacher education should engage future teachers in a lively knowledge building community. This should be a community that goes beyond the normal concerns with learning about educational theories and practices and developing teaching skills. It would be a community with design thinking applied to all the aspects of the world—scientific, social, moral, esthetic, and so on that teachers must attend to in their work—with idea improvement as the norm that they seek to establish in their own classrooms. Teachers, therefore, need to live in such communities themselves in order to be able to promote design-mode work with ideas by their students. Inasmuch as this is not something that will have been familiar to teacher candidates from their own school experience, preservice education ought to immerse them in it. In short, knowledge building should not just be something that teacher candidates learn about and receive instruction in how to teach; it should characterize their experience in teacher education.

Teachers themselves typically do a lot of work in design mode, but it is designing activities and lessons. It is not working in design mode with ideas. Both in teacher education and in subsequent professional meetings and workshops, ideas are dealt with in traditional justification mode fashion. They are things to argue about, criticize or advocate; they are not things to improve or reconstruct. Therefore the much bemoaned split between theory and practice is thoroughly institutionalized. Efforts may be made to "translate theory into practice," but in an intellectually alive profession there ought to be comparable efforts to "translate practice into theory" and a continual two-way interaction, with Knowledge Building a way of life for teachers as well as students. This requires sustained, connected dialogue among teachers with *idea improvement* a guiding purpose.

1.6 Technology to Help Students Take Responsibility for Idea Improvement

There is an abundance of digital technology available that can help students grasp ideas (through simulations and games, for instance), argue about ideas, and represent ideas in communicable form. All of these can play useful roles in Knowledge Building, but they do little to help students with what we have pointed to as the essence of creative knowledge work in modern times: students taking collective responsibility for idea improvement. This is not something that comes naturally to people, the way curiosity and argumentation do. Social support is needed. A classroom norm of continual idea improvement needs to be established, and with this goes a willingness to collaborate in advancing ideas as a public good and not only a personal good. Working to improve and not merely evaluate ideas means working with ideas in design mode, and this too is something that does not come without effort. Yet we have seen schools where even the youngest children engage in design thinking with ideas as if they were born to it. These are classrooms where creative idea development has become a way of life, a satisfying though continuously challenging way of life—just as it is in the world's leading centers of research and innovation. There is good reason to believe, based on comparison of these successful classrooms with more conventional inquiry-based classrooms, that technology plays a significant role.

What kind of technology can support knowledge building and the forms of discourse that serve to create new knowledge? We have been working at developing, testing, and refining such technology for more than 30 years, starting with what has been recognized as the first networked collaborative learning environment, which we prototyped in 1983.[5] Originally titled CSILE (Computer-Supported Intentional Learning Environment), it was rebuilt a decade later as Knowledge Forum (Scardamalia 2004), which is the name it still bears after numerous version changes that moved it from a client-server architecture to being fully web-based. Supporting knowledge building discourse has been the goal from the beginning. The basic ways of doing this have been the use of simple, customizable, non-scripted discourse supports (my theory…, a better theory is…., putting our knowledge together…), and a graphical interface where notes representing ideas can be organized and reorganized against user-created backgrounds that represent higher-level conceptual structures. Knowledge Forum developers continue to work on providing further kinds of support, guided by design principles such as the following (from Scardamalia 2003):

1. Support for self-organization that goes beyond division of labor.
2. Shared, user-configured design spaces that represent collective knowledge advances built from the contributions of team members.

[5]This was recognized in a career achievement award to the present authors at the 2005 CSCL conference.

3. Support for citing and referencing one another's work so that contributions to the evolution of ideas are evident and can become objects of discourse in their own right, much as is the case in the history of thought.
4. Ways to represent higher-order organizations of ideas and to signal the rising status for improved ideas as contrasted with their nondescript entry in threads, folders, and repositories where they are lost amid information glut.
5. Ways for the same idea to be worked with in varied and multiple contexts and to appear in different higher-order organizations of knowledge.
6. Systems of feedback to enhance self- and group-monitoring of ongoing processes and to tap idea potential—as distinguished from assessment and management tools used exclusively for filing, organization, and end-of-work or external evaluation.

One of the concerns teachers raise in using Knowledge Forum is that students contribute such a quantity of diverse ideas that the conceptual landscapes (as represented by note icons on the graphical views) become messy and over-crowded. We have resisted the traditional educational "solution"—to cluster or categorize ideas. Such categorization is frequently referred to as "finding big ideas," but we have yet to see the process leading to big ideas. Instead ideas are organized by topics, with some ideas dropped because they do not fit, some arbitrarily moved to one category because the method precludes representation in multiple categories, and some added to categories arbitrarily.

We are working instead toward technology that supports crisscrossing and rising above idea landscapes. Knowledge Building research has entered an intense phase focused on formative feedback and metadiscourse—components of the crisscrossing landscapes idea. This requires building tools to allow students to traverse the landscape of their ideas from multiple perspectives. Thus for example, their ideas can be visualized from the point of view of discourse moves represented in them, or on the basis of student-identified promising ideas, or semantic overlap with other knowledge resources (such as curriculum guidelines) to identify commonalities and differences. Research pertaining to each of these has been published (Scardamalia and Bereiter 2014a; Resendes et al. in press; Chen et al. 2012) so we do not go into detail here.

These publications report a number of technological innovations that have all had significant positive effects on students' knowledge building. Students and teachers see aspects of their work that are new to them, and from these new perspectives set a new course for their discourse. For example, students as young as 7 years of age noted that they had many theories but no evidence for them; they self-organized into new teams to determine if there is any evidence for theories they consider important. Through the use of another visualization they saw words in curriculum guidelines that they never used; they undertook spontaneously to investigate the missing terms and to incorporate the related concepts into their work. Another study, conducted with children a year older, showed that when students saw ideas they judged to be promising they made selections to drive their discourse forward (Chen et al. 2012).

The landscapes of ideas represented by Knowledge Forum views are populated mainly with students' own ideas, in the form of notes, although these notes often cite ideas drawn from outside sources, and content from outside sources may also be brought into the view landscape to be worked on along with the students' own productions. We envision students and teachers as collaborative designers of idea landscapes, with tools for crisscrossing these landscapes and viewing them from different perspectives. Achieving this involves fascinating design issues, which an international design lab is forming to pursue. New technologies for semantic and social network analysis and for diverse kinds of learning analytics are being incorporated into the new designs. The challenge here, as it has been from the earliest days of CSILE development, is to ensure that the technology supports higher levels of agency rather than the technology itself taking over the higher-level processes (Scardamalia and Bereiter 1991). The more powerful the technology, the more vigilance is required to keep cognitive responsibility in the hands of the students (Scardamalia and Bereiter 2014b). This means making the technology transparent, avoiding "black box" kinds of analysis as much as possible and having students make their own connections and find their own paths through the idea landscape. An important further challenge for the international design lab is expanding the knowledge building communities in which students work. Education is outgrowing the classroom in many ways. Drawing information from outside the classroom is something that web-enabled classrooms and web-enabled students already do. But bringing students fully into the Knowledge Age requires more than this. Students need not only to avail themselves of the knowledge advances being made in the larger world of knowledge creation, but they also need in some legitimate sense to be part of that larger knowledge-creating world. The present day "social web" is hardly a model for that, although it provides promising tools.

1.7 What Is Possible?

Learning one's way around in a conceptual domain by crisscrossing it in multiple unspecified ways, letting ideas follow their "natural inclination," as Wittgenstein put it, and rising above the "landscape" of ideas to contemplate the possibility of new, more powerfully integrated ideas: These represent a quintessentially systemic approach to education. Self-organization and emergence rather than instruction and guided practice are its dynamic elements (Bereiter and Scardamalia 2013). We are well aware of the opposition to such "minimally guided" education and of the strong evidence on which this opposition is based (cf. Kirschner et al. 2006). Prominent current approaches to a more guided instruction provide guidance via scripts (Weinberger et al. 2005) or use learning analytics to prescribe instruction (Dietz-Uhler and Hurn 2013). Although these approaches are typically directed toward prespecified learning objectives and paths toward attaining them, they are adaptable enough that one can imagine a "crisscrossing the domain" script. The question raised by Knowledge Building research is whether such stronger guidance is needed or desirable. The studies cited in the preceding section suggest that with appropriate tools and context young students take on considerable social and cognitive responsibility and explore conceptual domains productively on their own initiative. The argument we have been making here is that this is a better way to initiate students into a world where design thinking is the norm and where sustained creative work with ideas is paramount.

Knowledge Building is part of a long-term trend toward making knowledge itself an object of deliberate, design-oriented work. Schooling may lag behind that trend, but it cannot ultimately resist it. The profound changes that will eventually bring education into the Knowledge Age are not likely to come in response to outside pressures or new regulations. They will come about as the whole society—including teachers, parents, and policy-makers—internalizes and feels comfortable with the idea of creating and working with knowledge. As knowledge creation becomes increasingly familiar in various walks of life, it will become easier to grasp as an educational approach, and easier to distinguish from methods which only mimic its surface features. How long it will take for this to happen, we cannot say. However, we think it is safe to say that educators can speed up or retard the process.

Although Knowledge Building is working well and producing impressive results in a number of different settings (e.g., Chan 2010; Scardamalia and Egnatoff 2010), and school-government-university partnerships are advancing it (Laferrière et al. in press), it is clearly a work in progress as far as wide-ranging efficacy and full-scale implementation are concerned. A key concept in creative enterprises of all kinds is "promisingness." Creative design—whether it is producing a poem, a theory, or an educational innovation—always takes place in a context of uncertainty about outcomes, and thus requires a willingness to judge what directions of movement hold promise and justify further investment. That is the claim we would make about the educational approach discussed here. It is abundantly promising, especially in terms of the emerging needs of innovation-driven, problem-solving societies.

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Carl Bereiter is a professor emeritus, University of Toronto, and a co-founder with Marlene Scardamalia of the Institute for Knowledge Innovation & Technology. He is a member of the U.S. National Academy of Education and has been twice a fellow at the Center for Advanced Study in the Behavioral Sciences, most recently for participation in a study of the cognitive bases of educational reform. He has published widely on a variety of topics in instruction, the learning sciences, and educational policy. Recent publications include "Principled Practical Knowledge: Not a Bridge but a Ladder" (*Journal of the Learning Sciences,* 2014) and "Knowledge Building and Knowledge Creation: One Concept, Two Hills to Climb" (co-authored with Scardamalia; in *Knowledge Creation in Education,* 2014).

Chapter 2
ICT Supported Instructional Innovative Practice and Diffusion Mechanism of K-12 in China

Jinbao Zhang, Linglin Meng and Qianxia Jing

Abstract With the rapid development of technology and society, each country has emerged more innovative instructional practices in K-12 using new Information Communications and Technologies (ICTs). As an important representative, China has a long history of exploring and reforming the instruction. In recent years, there are lots of innovative instructional practices emerging with the development of ICT in education in China. The experiences of innovative practice, including the approach of innovation and diffusion model are important for every country. In this chapter, we analyze some typical instructional practices and relative models in China from eight approaches of instructional innovations which can be classified as three main missions: to realize education equality, to promote teaching quality, and to cultivate creative ability. It can be found that all these innovative instructional practices are combined with characteristics of the educational organization system of China and there are several influence factors for these innovative instructional practices, including government-supported educational institutions and enterprise, experimental team in school, technological innovation and educational needs, etc. Therefore, this chapter extracts typical educational innovative diffusion mechanism in China, which can be used as reference of ideas and inspiration in practice for other countries.

Keywords Instructional innovation · Innovation practice · Diffusion mechanism

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2.1 Introduction

For now, after several years of development, the technology has been widely applied in the instructional process in schools at all levels, and greatly promoted the teaching efficiency and to a certain extent, promoted the innovation and development of instruction. Considering the ponderous pace of change in formal education, it is a formidable task of shifting toward learning that fosters creativity and innovation, dislodging it from the "factory model" that moves students along the conveyor belt of schooling through successive grades of prescribed content. On a practical level, trying to infuse creativity, innovation, and entrepreneurship into existing education structures that favors conformity is destined to mute the potential positive impact of doing so. Ultimately, as Michael Fullan (2013) has suggested, what is required is an extensive makeover of education systems. One element of that makeover process, he proposes, is the use of "new pedagogies." This makes sense if we are to learn from the great hopes and expectations associated with updating education through greater use of technology—applied to conventional teaching practices. Simply adding technology to existing practice has not been nearly as transformative as expected. Rather, Information Communications and Technologies (ICTs) will be more effective when utilized with "new pedagogies". Moreover, the new pedagogies and makeover need to be associated with a coherent vision of education that has challenged outdated assumptions about the real purpose of education.

In order to cater to the development of technology and education, the Chinese government and educational institutions have explored a series of instructional innovation for regional and school practice. The Ministry of Education, P.R.C. has released the *National Plan for Medium and Long-term Education Reform and Development (2010–2020)*, which contains a number of strategies for education development and also proposes development goals for all levels of Chinese education. The Ministry of Education and the Ministry of Finance, in November 2012, jointly launched the implementation of the "digital educational resources cover all teaching sites" project (MOE 2013). The so-called teaching site is the school where is remote, small scale, and lack of teachers and infrastructure. All the teaching sites had been equipped with digital educational resources, receiving, and playback devices. Meanwhile, this project helps teachers to offer national curriculum, so that school-age children in rural and remote areas can be well-educated (Wei 2015). Innovative practices of education not only achieve success in the regional level of resource construction, but also in school level. In 2014, the initiative of *teaching with co-creations* launched by the National Center for Educational Technology for nationwide school teachers. All teaching materials created by teachers including real-time recorded video will be shared online, commented by other teachers, and finally conducted the competition. The excellent courses are used for reference by other teachers, which is beneficial in sharing of quality resources and improve teaching quality (Fu 2014). Faced with the uneven distribution of infrastructure, educational resources, and teachers in urban and rural school, the synchronous classroom is an effective mechanism of high-quality resources in rural areas covering a wide range of teaching sites and is essential to achieve sharing of high-quality education resources among schools by synchronizing activities of high-quality school's classroom through two-way video conference system (Yan et al. 2014). For example, No. 1 Middle School in Zhengzhou and No. 7 Secondary School in Chengdu are both using satellite to share quality teacher resources. Through satellite communication technology, high-quality resources are transmitted to schools in poor areas. For many rural students, it provides the highest quality education resources (Wang 2014). Some schools also actively explore ICT supported instructional innovative practice, such as *Flipped Classroom Teaching* in Changle No. 1 Middle School, which is a new trial to integrate ICT with teaching. It enables ICT to fully penetrate into all aspects of curriculum such as learning goals, teaching resources, curriculum structure, and instructional evaluation, so that ICT supported teaching and learning has become conscious activity for teachers and students (Dong 2014). No.2 Middle School in Zhengzhou exploring education transformation, takes advantage of mobile terminal and changes the way of teaching and students' learning to let students carry out self-regulated learning anytime and anywhere (Chen 2014). The maker education in Wenzhou Middle School successfully meets the needs of encouraging, sparking and developing student's creativity and practical ability, and makes students transforming from consumers to creators easier (Xie 2014). Luochuan Middle School in Shanghai carries on project-based learning, setting their teaching goal as improving students' twenty-first century skills by integrating subject knowledge, subject tools, Web 2.0 technology, and other resources (Jiang 2009). All the above literatures are based on the practice of educational innovation, but mainly concentrated on studying special innovative teaching mode or analyzing certain case, ignore the effect and internal affective factors of educational innovation from a macro perspective. The theoretical research on these problems can enrich the knowledge of innovative education.

Diffusion of Innovations is a theory that seeks to explain how, why, and at what rate new ideas and technology spread through cultures (Roger 1995). It has been used to systematically analyze thousands of innovative diffusion cases. Rogers proposes that four main elements influence the spread of a new idea: the innovation itself, communication channels, time, and a social system. Ely (1999) identified the following eight conditions that appeared to facilitate the implementation of education technology innovations: (1) dissatisfaction with the status quo; (2) existence of knowledge and skills; (3) availability of resources; (4) availability of time; (5) rewards or incentives exist; (6) participation; (7) commitment; and (8) leadership. Michael Fullan's change describes features of professional learning communities that promote change and how to embed change in practice (Sparks 2003). Fullan and Stiegelbauer (1991) identified three areas of the major factors affecting implementation: characteristics of change, local characteristics, and external factors (government and other agencies). After that, based on the angle of the process, the process model (C-R-E-A-T-E-R Model) clearly embarked upon the change process in The Change Agent's Guide (Havelock and Zlotolow 1995). This model includes six periods: Care, Relate, Examine, Acquire, Try, Extend, and Renew.

This model also explains the example of each stage and the focus of the specific work. The *Concerns-Based Adoption Model* (Hall and Hord 1987) provides tools to "keep a finger on the pulse" of change and to collect the information needed. The model's guidelines help readers to understand the different concerns that stakeholders experience as change progresses. This, in turn, will help readers to design and enact interventions when they will be most effective. Tumeniene (2002) conducted research on the research of innovative activities features of Lithuanian secondary school teachers. In the aspect of classification on the teachers' innovative activities, based on S-curve innovative diffusion theory, Vitalija Tumeniene came up with a more comprehensive model of teacher innovation process. By examining the results of survey assessments of the eBook project, Martinez-Estrada and Conaway (2012) analyzed how the eBook supported student learning and course outcomes. Panagiotis etc. (2013) analyzed seven cases of ICT-enabled innovation for learning from Europe, Denmark, Hong Kong SAR, Japan, Singapore and South Korea, covering aspects such as scale and nature of innovation, learning outcomes targeted, the role of technology in the innovation, and the implementation strategies. The lessons learnt about the necessary conditions for sustainability, scalability and impact at the system level are also discussed. Zhang (2013) argued that the research on innovative diffusion mechanism of educational technology is to abstract internal logic mechanism in a complex system. Technical diffusion research should concern the process by which an innovation is communicated through certain channels over time among the participants in a social system.

Overall, up to now, the innovation and development of education, from a practical and theoretical research has made great progress, but still lack of macro understanding about instructional innovation. Educational innovation is a systematic process, requires in-depth analysis and research. Therefore, based on previous research and theory, this chapter tries to refine innovative features and innovative diffusion mechanism from a macro perspective, by studying innovative practice a typical case of China, which has great influence on contemporary educational innovation.

This chapter includes five parts. First part introduces general development of ICT supported instructional practice in China. Second part is on research design, including the research framework and research methods. Third part introduces current innovative instructional models and practice in the K12 mainland of China. Based on the study of typical cases, the fourth part analysis the main characteristic of innovative instruction in China. The last part discusses the focus point of government, scientific research institutions, and practitioners in the diffusion process of innovative instruction, and typical model of education innovative diffusion in China. This chapter not only analyzes and summarizes the nature of Chinese education philosophy and innovative diffusion strategies based on case study, but also analyze instructional innovation from a macro view, which has certain reference and enlightenment in instructional innovation for each country.

2.2 Development of ICT Supported Instructional Practice in China

Along with the process of social transition, educational transformation, and spreading of ICT in society, the development of ICT in education in China mirrors its international development. If we consider the proclamation that "computer education should start from children" by Deng Hsiao-ping as the starting point of ICT in education in China, it can be divided into four phases: (1) *Instruction of computing as a discipline* starting from the end of 1970s, (2) *Computer assisted instruction and management* starting from the middle and late 1980s, (3) national initiatives focused on *ICT construction of infrastructure in education* since late 1990s, (4) national projects of ICT in education focused on *improving capacity of using ICT* since 2005 (Huang et al. 2006).

Since 1970s, a series of national projects and policies of ICT in education have been implemented, laying a solid foundation for its sustained development (Meifeng et al. 2009). From the changing process of education technology infrastructure in primary and secondary schools, China has experienced the development process of countries to promote the building of audio-visual education facilities to the computer and network-based modern education technology facilities. After the year of 2000, ICT in education in China has entered the phase of comprehensive and rapid development. Due to the implementation of national policy and the follow-up of government special fund, the launch of "school-to-school" project inspired a flood of the construction of ICT-based education in primary and secondary schools and the investments of ICT-based education also bullish all the way. For the clear and specific time requirements, a large number of schools began to speed up the purchase of equipment, build computer lab and construct the campus network and metropolitan area network (Huang et al. 2007).

In 2012, the Ministry of Education of the People's Republic of China issued "*National Development Plan for ICT in Education (2011–2020)*." This plan makes an overall design and comprehensive deployment for the next 10 years of ICT-based education work. Its basic objective is to build an ICT-based education system which covers all levels of urban and rural schools, promote the deeply integration of ICT and instruction to realize the comprehensive innovation of education thought, idea, method, and means by improving the quality of education, promoting educational equity and building a learning society (MOE of P.R.C 2012). By the end of 2014, the proportion of learning terminals ownership is 10 %, funding of ICT in education accounts for 11 % of total education funding. Nearly 30 % of primary and secondary schools have school-based digital repository, about 70 % of schools can share resources through the campus network. 80.6 % of primary and secondary schools realized Internet access, 59.6 % of ordinary classrooms have been equipped with multimedia teaching equipment in the whole country.

As for the great improvement, China is strengthening international exchanges and dissemination. There are also many innovative instruction practices emerged. In May 2015, UNESCO's *Conference on ICT and Post-2015 Education* was held in Qingdao.

The conference seeks to create an interface between education and ICT sectors to debate on how ICT can be leveraged at scale to support the achievement of post-2015 education targets. Under the core theme of leveraging ICT to support the achievement of post-2015 education targets, the conference looks forward to debates, shares the cutting-edge knowledge and ICT solutions, and devoted deliberation on sector strategies. In order to showcase the recent development and achievements of ICT in education, most of the Chinese provinces and Municipalities recruit and select some typical representatives of innovative instruction practice and demonstrate all these cases during this conference.

The authors collect all those cases as object of study in order to make sure the characteristics and diffusion mechanism of Chinese innovative instruction practice in K12. Before this chapter, a preliminary study indication has been done. According to the diffusion scale, all the educational innovations can be divided into three categories: (1) *large scale of diffusion* includes innovation and transformation of teaching resources and teaching processes; (2) *medium scale of diffusion* includes motivate educational approach, curriculum provision, and alterative learning environment; (3) *small scale of diffusion* includes systematic instructional design, learning evaluation, social learning activities, etc. It is also obvious that large scope refers to the innovations that can be carried out in most schools, the medium scale refers to those that can be conducted in one part of schools, and the small scale refers to those that can be conducted in some high quality schools. Although there are obviously differences, all these educational innovation practices make great effect and diffusion in these three different levels. There is more in-deep research to be done to make sure the rules of innovation and diffusion mechanisms.

2.3 Research Design

2.3.1 Research Framework

The needs for innovative education coming from economic and social development become increasingly urgent, and require suitable measures of reforming from the aspect of instructional process, teaching mode, instructional structure, teaching method, learning content, etc. As the influence of ICT in education has become increasingly obvious, it also has different levels of influence on the educational innovation at the same time. Innovative instruction practice is the core of education reform; the traditional education is mainly about teachers' knowledge transformation while the new teaching mode is given priority in the learning process.

In fact, there is no sole or single innovative way. According to the previous analysis, we can find all the innovative practices that can be categorized into eight dimensions. In order to analyze the main characteristics of variety innovation, this study defines eight types of educational innovation as Dimensions of Innovation listed in Table 2.1.

Table 2.1 Analysis dimensions of educational innovation

Diffusion scale of innovation	Dimension number	Dimensions of innovative instruction
Large	D1	High quality digital learning resources
	D2	New teaching and learning process
Medium	D3	High motivative educational approach
	D4	Multi-optional curriculum
	D5	New learning environment
Small	D6	Systemic instructional design
	D7	New evaluation and assessment
	D8	Social learning interaction and activity

2.3.2 *Research Methods*

There are many factors related to implement successfully an innovative instruction. According to the framework with eight dimensions of innovative instruction, this paper choose some typical representative cases from the excellent cases which are collected with reliable information during *UNESCO's Conference on ICT and Post-2015 Education*. General information of eight cases is listed in Table 2.2.

Table 2.2 General information of selected cases in the study

Dimension	Name of school	Instructional features	Typical of school	Innovation diffusion area
D1	Case1: Chengdu No. 7 Secondary School, Sichuan Province	High quality schools live satellite synchronous classroom	High school	West China
D2	Case2: Changle No. 1 Middle School, Shandong Province	Flipped classroom teaching	High school	Southwest China
D3	Case3: Jingshan School in Beijing	Intelligent robot activity	Full school (grade 1−12)	East China
D4	Case4: Wenzhou middle school of Zhejiang Province	Maker space	High school	East China
D5	Case5: Zhengzhou No. 2 Middle School, Henan Province	Teaching by tablet computer	High school	North China
D6	Case6: Harbin Xiangbin primary school, Heilongjiang Province	Competency-based learning supported by ICT	Primary school	Northeast China
D7	Case7: Network evaluation system of Tsinghua University	Self-enrollment and selection of personnel evaluation system	High School	East China
D8	Case8: Zongbei primary school in Chengdu, Sichuan Province	Collaborative computer-supported learning	Primary school	Southwest China

We summarize lots of theoretical knowledge-books which have guiding significances on the research through sorting, analysis, inductive thinking, and summary. The literatures help us understand the perspectives and ideas of the related researches in domestic and foreign countries.

In this chapter, we collect sufficient information of the cases through various channels. Through the analysis of the model and effect of different types of cases, we try to reveal the characteristics, unique value, and internal rules of innovation and diffusion by using qualitative analysis method to sum up and reveal the new instruction practice.

2.4 Current Innovative Instructional Models and Practice in K12 in Mainland of China

2.4.1 High Quality Digital Learning Resources

At present, China has more than 10 million teachers, but the teachers' shortage is still critical. Thus, the share of teachers becomes a necessary and vital issue in China. The way of long distance live-transmission turns teaching resources into high-quality digital resources to share for a larger scale. In China, the model of long distance live-transmission classroom has been widely recognized, which makes schools share qualified teachers to solve the teachers' shortage.

(1) Scenario

In China, teachers' level and education level has a large gap between different areas. In order to take high-quality resources to rural and remote areas, the school of case 1, as a high-quality school, through the use of long distance live-transmission classroom to share good teacher resources to substandard school, where mainly concentrated in Yunnan, Guizhou, Shanxi, Sichuan, etc.

The whole teaching processes are delivered by Chengdu No. 7 Secondary School including the teachers' interactive white board, video, and voice. Moreover, Chengdu No. 7 Secondary School can have live interactive lecturing conference with these schools and teaching, lesson preparing, practicing, and testing are all synchronous in schools. To guarantee the quality of teaching, every lesson should be a collaborative work by monitors, instructors, subject teachers, and technical assistants.

(2) Model

Depending on specific teaching aims, live-transmission and synchronous classroom teaching usually have two different ways to implement about individual themes of collaboration and regular classroom collaboration. The main process is as follows:

First, setting up essential facilities is needed. In order to achieve real-time interactivity, the designated classroom should be equipped with computer network broadcast systems, camera, microphone, speakers, and other facilities.

Second, making synchronous teaching plan is oriented by center school. The remote school would carry out synchronous classroom according to the teaching plan. During synchronous classroom, the course is taught by teachers of center school and other schools' classroom connected to the center schools' classroom via live system, which can achieve interactivity.

Finally, based on their actual situation, the remote school raises issues and communicates with central school to facilitate remote synchronization teaching to reach optimal effect.

(3) Benefit

- Reducing the gaps of education resources between urban and rural areas.
  Sending high quality of teaching to distal school narrows the gap of education level between urban and rural areas, such as Chengdu No. 7 Secondary School uses regional fiber optic network, satellite network to provide services of classroom synchronization to nearly 20,000 students, 142 schools, including Yunnan, Guizhou, Tibet, Gansu, Shanxi and Sichuan Province countryside, etc.
- Improving teachers' professional level and promote teachers' professional development.
  To make remote synchronization carried out smoothly in the classroom, teachers need to work closely with both sides to share resources, experience, ideas, and promote each other jointly. In order to have a more in-depth understanding, the ICT application should be concerned.

2.4.2 New Teaching and Learning Process

The teaching and learning process is an important part to achieve the goal of education and it is also an important way to improve the quality of teaching. The traditional teaching process in general is as follows: the organizations of teaching, review inspection, teaching new courses, consolidation exercises and assignments. With the deepening reform of new curriculum, this teaching process gradually revealed its limitations. Appearance of flipped classroom subverts the traditional teaching process, which makes students to be the masters of learning and promote the development of students' practical ability and creative consciousness. In case 2, the teaching practice has changed based on the original process of flipped classroom, which is more indigenization.

(1) Scenario

With the depth development of ICT in education, "flipped classroom" as a new teaching model has become a hot topic of research and it has a significant impact on teaching reform of education.

The school of case two has 146 classes in 7–12th grades where flipped teaching has been implemented for all subjects. In their flipped teaching implementation, there are two stages: self-questioning and training-demonstrating. The self-questioning stage consists of five segments, namely guiding the goals, self-learning the materials, assisted by micro video, cooperative learning, and online evaluation. The training-demonstrating stage also consists of five segments, which are breaking through the difficulty, training how to demonstration, promoting the cooperation, coaching the evaluation, and summarizing the reflection. Teachers have built a course resources system called "Studies the document + Micro-class + Instructional design." They have also created a teaching research system which includes curriculum establishment, school-based research, teacher and student training, and development of learning plan. An interactive digital learning platform has been developed for tracking students' learning process of recording, feedback, analysis, and evaluation (Fig. 2.1).

(2) Model

Pre-class, teachers need to design for self-learning resources according to the characteristics of knowledge such as video recording teaching by themselves or other teaching resources. Teachers based on their teaching experience record multiple versions of content to adapt to different needs of students. Before class, the teacher can use the network to support students' learning. Students can communicate with fellow students through message boards, chat rooms, and other Internet communication tools, which can promote understanding and learning between each other.

In-class, there is more time for teacher−student interaction, so teachers should take advantage of the situation, cooperation, conversation, and other factors to bring students' initiative into full play through designed activities. For example, teacher can carry out teaching activity to guide students to ask questions, analyze problems, collaborate, start brainstorming ideas, and share the product and feedback. Compared with traditional classroom teaching, in this session, the role and position of teachers has undergone great changes. Teachers need to increase the depth of discussion among students, which need to give more targeted guidance based on teacher–student interaction.

Fig. 2.1 Flipped classroom in Changle No. 1 Middle School

Post-class, students deal with learning contents and control learning progress by themselves. Teachers adopt the guidance and collaboration to meet the learning needs of students and personalized learning process.

(3) Benefit

- Improve academic performance
  Flipped teaching improves students' initiative. This knowledge construction strategy reduces the difficulty of knowledge and increases interaction between teacher and student, which can improve students' academic performance.
- Promote learning occurrence
  After class, student should learn by themselves according to high quality resources provided by teachers, which can complete the transfer learning process of knowledge. It enables students to follow their own pace to learn, and achieve one-to-one personalized guidance. When students need help, the teachers and other students would help them. Students can get instant feedback and correction. It enhances students' interest in learning and promotion in learning happens.

2.4.3 High Motivated Educational Approach

With the development of computer technology, bio-technology, mechanical technology, electronic technology, and other fields of knowledge, the intelligent robot research has become a hot issue. The purpose of robot course is to motivate students to take part in competitions. It stimulates students to pursue knowledge, which is an extremely effective educational approach to improve students' motivation. At present, China has emerged a group case of robots education practice as activity curriculum and organized many competitions to improve the students' enthusiasm to participate in them. The practice of case three has been widely recognized.

(1) Scenario

With the rapid development of communications technology, virtual reality technology, science and technology, and cognitive learning theory, robots have been developed to promote students' learning. The case three is a specialized education test in a primary and secondary school. In 2000, teachers participated in the training course on intelligent robots. After the training, they started to carry out scientific and technological activities using intelligent robots. Intelligent robots give students a panoramic view of ICT, and students can give full play to the imagination to develop a variety of intelligent product, which can cultivate their scientific and technical development ability.

After students finish working, they can participate in various scientific and technological activities, vehicle model competition, science and technology production competition, science and technology class meetings, computer robotics competition, etc. Students who win the competition will be given material rewards and honors, which can inspire other students to learn.

(2) Model

Students acquire knowledge through hands-on practice. They are like real engineers to select research themes for the project, plan, design, assembly, and test. The small groups use blocks, sensors, motors, and gear components to design their own robots, and write a program to control the product. The main flow is as follows: concept and analysis, and pay attention to their legitimacy; plan and design, students should conceive it based on design and use a pencil to draw up a draft and the teacher should explain the method during the process. Then the group works together to finish the task and then tested and commented under the guidance of teachers.

(3) Benefit

- Motivate student interest
  In robot teaching, the robot is just a carrier through which teaching and competition are carried out to effectively promote students' learning and motivation.
- Expand students' scope of knowledge
  Robots' teaching is not merely related to the content in the class, but also involves blended knowledge in other general curriculum, including energy, materials, tools, and design. Robot technology covers the basics of ICT and general technology, which can broaden students' knowledge.

2.4.4 Multi-Optional Curriculum

With the development of economy, science, and technology creative thinking and design ability in education gets more attention. Design-based learning is used to help learner acquire the knowledge and skills in various fields through integrating education-related aspects of innovation and professional knowledge. The traditional course can no longer meet the demands of students, and a multi-optional curriculum should be designed to find and satisfy demand. The instructional practice of case four creates Maker Educational courses, which can be described as a successful case and has been widely recognized.

(1) Scenario

With the 3D technology, open-source hardware platform has become more popular, the trend started to focus on the capability for personalization in recent years. In case 4, the school integrates design-based learning in the group activity to conduct the creative education. It provides a place for students to create, and a multi-optional curriculum to choose for students. The Maker Space was created by this school in October 2013. This space uses Arduino as the platform for the courses of Maker, which is suitable for large class teaching. Different hardware, such as Raspberry Pi, Banana Pi, pc Duino is used for the group learning demonstrations. 3D printers and laser engraving machines are also used for printing out students' works. The Maker Space provides students a place to transfer their creativity into real world objects as well as transforming Maker Education from theory to practice (Fig. 2.2).

Fig. 2.2 Maker space in Wenzhou Middle School

(2) Model

Design-based learning includes three basic components: (1) Conceptualization of the task: learners accept to the challenge from teachers, clearing tasks of project by brainstorming ideas, and possible solutions to solve the problem (2) Establishments and tests of the solution: learners choose a feasible method to design and create; forming models; learner show their products to others, redesign and modify the products according to others' proposal; retest. Learners continue to find the techniques and methods to modify the products. (3) Sharing and gaining the knowledge: through research, learners share solutions and discuss with others, which can acquire more knowledge. In this model, teachers ask students to design a material object by themselves, such as a car model, in order to inspire students to have their own knowledge and skills for designing and implementing their design plans. In the process of implementation, students can keep learning new knowledge and skills through the continued modification and redesign of their design plans.

(3) Benefit

- Be conducive to individualization development
  Multi-optional curriculum encourages students to follow their own interests to choose. It helps students develop their interest and promote the individualization development.
- Improve students' interest
  Maker Education breaks the way of traditional teaching, by a series of experience and achievement, so that students can learn in a more active learning environment, which enhances the students' interest.

2.4.5 New Learning Environment

The emergence of printing greatly contributes to the development of human culture, since people could record the practice or skill and develop some technical knowledge preserved in the form of text. In the Information Technology Environment, intelligent multimedia educational software has good interaction. Presenting teaching content by sound, animation, high-quality video, audio can be more dynamic, and visualization. For example, new learning environment like tablet PC, not only makes learning more self-directed, but also more free and diverse. Learning behaviors can be more individual and cooperative. In case 5, the tablet PC has been used as a normal tool in the new learning environment and have won initial success.

(1) Scenario

Currently, it has been tens of thousands of classes using iPad and other mobile devices to teach in China. These types of classes could access to networking, digital learning resources and students have high participation.

Experimental educational innovation of ICT in the school is the fundamental method to promote changes in teaching concepts and teaching methods. In case 5, the school received special attention and support from Apple (China), and established a strategic partnership with Henan Normal University, East China Normal University and other research institutions. With the support of researchers, this school has implemented a self-regulated learning model by using ICT. Nearly 78 classes, 217 teachers, and 5000 students have already started using that in this school. The school has set up ICT innovation experimental classes, in which each student is provided with a free tablet to build e-learning environment. The resources of instructional design, courseware, teaching cases, and reflection have been integrated in a platform to facilitate mobile self-regulated learning. Students regulate their own learning and the teacher can track students' learning processes and performance. The school provides "four types of lessons" which include prerequisite lessons, feedback lessons, reflection lessons, and practice lessons. This new type of learning environment enables students to learn more independently.

(2) Model

First, the teacher should define the teaching topic, construct the teaching situation and teaching content, and develop digital teaching resources based on mobile devices. Second, the teacher defines the appropriate learning tasks for each study group. Moreover, providing students with learning resources, organizing students to carry out inquiry-based learning and discussion. The last thing is to provide concentrated guidance comment on the results of the discussion for students and form evaluation reflection.

(3) Benefit

- Improve academic performance

  By using tablet PCs, teachers can convey the resources to students in advance. It can also take advantage of audio and video tool to record students' oral and situational dialogue, and presentations allow students to complete work and display their outcomes. It improves students' cognitive competence and enhances teaching efficiency. Meanwhile, the tablet enables students have individual learning and evaluation, which makes teaching more targeted.

- The transformation of roles between teachers and students
  Mobile devices increase the level of independent learning. Teachers start to guide students to learn, and students, as masters of learning, strengthened their learning initiative, which are transforming the role of teachers and students effectively.

2.4.6 Systemic Instructional Design

Systemic instructional design is important in instructional innovation, which highly requires the teachers' teamwork. Instructional system design is mainly to promote learners as the fundamental purpose. It can apply teaching theory into the teaching objectives, teaching content, teaching methods, teaching strategies, teaching evaluation and create an effective "process" or "procedure." Systematic instructional design can improve teaching efficiency in classroom, and promote students' understanding and application. In case 6, the school summarizes the systemic instructional design for their school, which has achieved certain results and drawn greater attention.

(1) Scenario

Case six has sorted out the knowledge system of various disciplines based on the development rules for the discipline competency. The individual learning activities are supported by ICT to design systemic instruction and develop the competency-based learning for improving the core literacy of students in the twenty-first century. The school has developed successful models of competency-based learning for the disciplines of natural science and social science through many years of practice. Students have been trained to have the abilities of independent observation, active thinking, good communication skills, and knowledge building collaboration through the implementation of ICT. In classroom teaching, the five teaching activities, namely the problem-driven, the idea discovery, the experience exploration, the sharing outcome, and the comprehensive implementation, guide students to gain the above abilities. The experience of this school's success in using ICT in education can be illustrated as phase-by-phase promotion of ICT in education, as shown in Fig. 2.3.

(2) Model

Problem-driven: Design learning problem or task helps to stimulate students' interest. The task should not be fully resolved with prior knowledge, and require a structured multidisciplinary knowledge.

Idea discovery: Supporting students to discover the application of existing knowledge and complete the task during the process, students find some unsolved

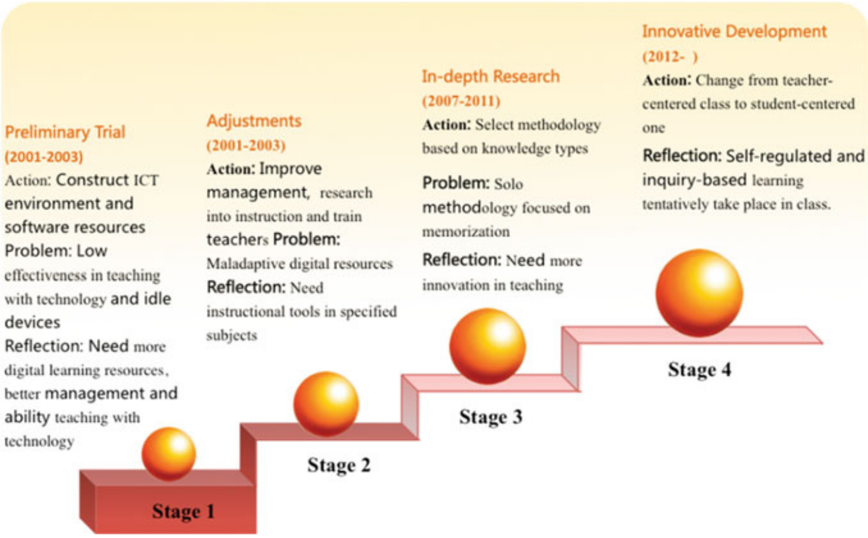


Fig. 2.3 Phase-by-phase promotion of ICT in education in Xiangbin Primary School

questions and they explore and summarize what knowledge can be used to solve the questions under the guidance of teacher.

Exploration and experience: Providing appropriate environment and tools or the resources contribute to the understanding of knowledge, which can help students complete the construction of knowledge.

Achievement sharing: Sharing individual learning outcomes and promoting the growth of collective intelligence.

Comprehensive application: Training students to master knowledge by the complex issues and help them to be proficient.

(3) Benefit

- Promote students' understanding and application
  Systemic instructional designs give students the challenge to acquire systematic knowledge which improve their academic performance and enhance the interest. And students could have a deeper understanding of knowledge and facilitate to apply what they learn into practice.
- Develop students' capabilities
  This mode pays close attention to the competency-based learning which is essential to the development of students. It can solve common scarcity of learning ability, creative ability and practice ability to meet the need of social and employment market.

2.4.7 New Evaluation and Assessment

With the development of education, educational evaluation has got widespread attention. Traditional evaluation and assessment is mostly focused on the results instead of the learning process. A new evaluation method promoting students' sustainable development has become an urgent need to improve the quality of education. Therefore, we should establish a new evaluation and assessment of education, building students' development evaluation system. It not only promotes students' well-around development, but also enables evaluation more objective and fair. Practice of case seven makes college enrollment become more equitable and effective.

(1) Scenario

China's college entrance examination has many limitations, and the lack of comprehensive and process evaluation comes first. Supreme mark aggravates the unfairness of the competition of the entrance examination. And teachers teach for the sake of the students' high scores and neglect the needs of students and the function of testing. Tsinghua network evaluation system sends profiles to the college admission office and the profiles are reviewed by the network evaluation committee experts, which can be used for the students' enrollment. Network evaluation is divided into two main levels, including "basic knowledge and basic skills assessment" and "online research." The online research encourages students to choose the subjects by themselves, especially combine with the technology research activities, computer activities, essays of arts activities, which was carried out by the university. The "network evaluation" truly becomes an evaluation system, which combine high school teacher with experts working together to guide the process of education. The evaluation results will be an important reference for Tsinghua University to enroll the students. Currently, Tsinghua University has invited four science experiment schools, including Tsinghua University High School, Peking University High School, Beijing Normal University Affiliated Experimental High School, and Huadong Normal University Affiliated 2nd High School to join in the comprehensive quality assessment project.

(2) Model

Network evaluation system uses servo recommendation. First, the submitted students' work will be recommended by an assistant professor. Then a professor will give further recommendation. In the end of the academic activities, professors give comprehensive performance evaluation and recommendation according to the students' behavior during the event.

At the end of the whole event, the file which acquired comprehensive recommendation access to a number of professors' summative assessment. The final qualified files will be sent to the University Admissions, which is used for selection of talents for university.

(3) Benefit

- Ensure the scientific selection
  This new evaluation tool greatly reduces the complexity of the process evaluation, which increases the efficiency. It is more focused on the learning process, making evaluation more objective and scientific. What's more, the assessment of process betters the teaching through consistent feedback possessing and all-sided characteristic.
- Benefit the students' all-round developments
  In the process of industrialization, the education reform of China must implement competency-based education, and this evaluation method is not only focused on students' knowledge, but also paying close attention to their comprehensive quality ability. It makes it possible to combine the process evaluation with formative evaluation and measure cultivation of the students' all-round development.

2.4.8 Social Learning Interaction and Activity

With the progress and development of society, the cultivation of twenty-first skills has become a key point. Social learning activities improve the communication between people and acquirement of new knowledge. The plan of collaboration and establishment guides students to actively construct learning, and cross-discipline knowledge building expands students' learning experience to develop twenty-first century skill. Practice of case eight describes that the school builds a collaborative knowledge construction platform, to support social learning interaction and activity.

(1) Scenario

Since August 2010, the school of case eight has provided a collaborative computer-supported platform, called Knowledge Forum. In this forum, students are guided to collaborate and interact in groups for co-creating group knowledge. For example, in geography classroom of 5th grade, a student proposed a question, "If I was running faster than the speed of earth's rotation, what would happen?" The teacher then guided students to expand this question in this forum for launching conversations and discovery activities. Students post their own ideas and opinions in this forum publicly and share their comments, questions, improvements, and summaries, and then achieve the goal of knowledge sharing. The philosophy adopted here is that learning should be "posting your own ideas" and that teachers are not only ones who teach in the classroom.

(2) Model

Collaborative knowledge construction teaching process generally includes five steps: ① Students grouping: the teacher divide students in different study groups according to gender, interests, learning standards, communication skills, a sense of discipline, etc.; ② Goal determination: teachers and student jointly develop learning goals for each lesson according to the outline of requirements and the practice in the book; ③ Methods teaching: teachers should provide students with the transitional bridge from the known to the unknown and students learn to think the teaching content independently; ④ Cooperative learning of groups: teachers take part in group learning and make the necessary guidance and regulation in the group learning process; ⑤ Comments and conclusions: after every group present their outcomes, the teacher should give guidance and reflection about the learning performance.

(3) Benefit

- Promote exchange, learn from each other and develop twenty-first century skills
  Collaborative knowledge building can promote students to communicate with other learners, and learn to absorb the useful perspectives of others to enrich the knowledge, thus inspires the learners' emotion and involvement in the learning process. Knowledge accumulation and sharing in collaborative learning are the core capability in the digital life, through which the positive teaching effect is achieved.
- Changing traditional roles of teachers and students
  Taking part in cooperation, students have a greater sense of responsibility and obligation to finish their task and they are more concerned over each other. Students have the initiative to study, which transforms the teacher's role to be an organizer.

2.5 Main Characteristics of Innovative Instruction in China

By further analyzing the content of these eight cases above, we summarize some key points of education practices, which mainly include Change Facilitator, Intention of Change, Instructional Model, Instructional Process, Learning Outcomes Targeted, and Benefit. These points of each case are shown in the following table (Table 2.3).

The theory of Innovation Diffusion is associated with the aspects of change facilitator, intention of change, instructional model, instructional process, learning outcomes targeted and benefit which are mentioned above in different degrees. Different change facilitator makes different impact on the corresponding purpose and the innovative diffusion scopes and effects. Different intentions of change also make different impacts on the instructional models and benefits of educational innovative diffusion. It will be analyzed in detail in "Influence Factors of Innovative Diffusion" part and "Typical Diffusion Model of Education Innovation in China" part.

Table 2.3 Main characters of innovative instruction

# of case	Change facilitator	Intention of change	Instructional models	Instructional process	Learning outcomes targeted	Benefit
Case 1	Practitioner	Educational demands	Live-transmission and synchronous classroom of high quality schools	(1) Setting up essential facilities	Acquirement of knowledge	Reducing the gaps of education resources between urban and rural areas, improving teachers' professional level
				(2) Making synchronous teaching plan		
				(3) Developing synchronous classroom		
				(4) Sharing high-quality resources of examinations and lesson preparations		
Case 2	Practitioner	Educational demands	Flipped teaching	(1) Pre-class: teachers record micro-lectures in advance and students learn these micro-lectures by themselves	Acquirement of knowledge, basic capability	Improving academic performance, promotion in learning happens
				(2) In-class: teacher and students communicate and interact to consolidate knowledge		
				(3) Post-class: students deal with learning contents and control learning progress by themselves		
Case 3	Practitioner	Development of new technology	Intelligent robot activity	(1) Drawing the draft through design and analysis	Innovative capability	Developing students' innovative capabilities, expanding students' scope of knowledge
				(2) Assembling robots by group cooperative learning		
				(3) Testing and making comments		

(continued)

Table 2.3 (continued)

# of case	Change facilitator	Intention of change	Instructional models	Instructional process	Learning outcomes targeted	Benefit
Case 4	Practitioner	Development of new technology	Design-based learning	(1) Conceptualization of the task	Development of personal capability and interest	Improving students' interests, developing students' innovative capabilities
				(2) Establishments and tests of the solution		
				(3) Sharing and Gaining the knowledge		
Case 5	Research institute	Educational demands	Teaching by tablet computer	(1) Defining the teaching topic and developing digital resources	Acquirement of knowledge, basic capabilities	Improving academic performance, transforming roles between teachers and students
				(2) Refining the detail of learning tasks and providing learning resources		
				(3) Organizing inquiry-based learning and discussion		
				(4) Provide concentrated guidance		
Case 6	Research institute	Educational demands	Competency-based learning supported by ICT	(1) Problem-driven	Promoting the understanding of knowledge, application, and migration	Improving students' interest, developing students' capabilities
				(2) Idea discovery		
				(3) Exploration and experience		
				(4) Achievement sharing		
				(5) Comprehensive application		

(continued)

Table 2.3 (continued)

# of case	Change facilitator	Intention of change	Instructional models	Instructional process	Learning outcomes targeted	Benefit
Case 7	Research institute	Educational demands	Self-enrollment and selection of personnel evaluation system	(1) Reviewing works of students	Basic capabilities	Scientifically selecting talents, leading students developments all-round
				(2) Recommending by an assistant professor		
				(3) Recommending by a professor		
				(4) Comprehensive assessments, the final assessments of comprehensiveness recommended by many professors		
Case 8	Research institute	Educational demands	Collaborative computer-supported platform	(1) Arranging students in group	Acquirement of knowledge, basic capabilities	Promoting the communication, developing twenty-first century skills, changing roles between teachers and students
				(2) Determining the goals		
				(3) Teaching relative methods		
				(4) Cooperative learning in group		
				(5) Making Comments and drawing conclusions		

2.5.1 Impact of Innovative Instruction

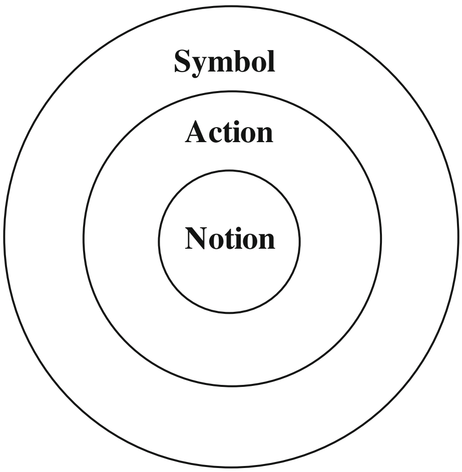
From the perspective of sociology, the core concept of research is through the symbol of writing materials such as slogans, regulations, documents or even literatures to explore practical behaviors, and then reflect the core idea or notion by these, as shown in Fig. 2.4. In this chapter, we summarized the behaviors' effects and influence of different cases from the characteristics above, it will help to promote the development of practices of innovative instruction in macro level.

(1) Promoting Educational Equity

Promoting educational equity is the foundation of innovative instructional. Currently, the problem of unbalanced social and economic development in different regions and between rural and urban areas still stands out in our country even in the world. More than 30 % primary and secondary schools are distributed in rural areas; because of the restrictions of the geographical position, school conditions and teachers' level in those rural schools, there are huge gaps of educational quality between urban schools and rural schools. Therefore, promoting the balanced development in regional or urban-rural areas disparities is the focus of basic education policies of the government. The innovation of districts' management system is not the average allocation of educational resources simply; it is to improve school-running standards and education quality synchronously. Normally, the college entrance examination system in China only pays more attention to students' scores and ignores their performance of learning. So the innovative instructional practice such as long distance live-transmission classroom and online evaluation enrollment system are all welcome.

- Long distance live-transmission classroom
  Through the ways such as long distance live-transmission classroom or online classroom high quality resources can be shared to rural students and teachers. In

Fig. 2.4 Three layers of study on theory of sociology



these ways it can narrow the educational gap of different regions, urban and rural or different schools and promote educational equity.

- Online evaluation enrollment system
  By the online evaluation and enrollment, educators can have a comprehensive understanding of student's performance. It is the selection of combining formative evaluation and summative evaluation that pays more attention to the students' ability and comprehensive quality and helps to keep equity in the process of selection.

(2) Improving Educational Quality

In order to drive the development of society, it is the necessary to improve the overall quality of laborers. Many changes and characteristics of laborer's quality are presented along with social transition and economy development. With the development of ICT, practices of innovative instruction began to emerge constantly, which aim to enhance education quality. Those practices include Flipped Teaching and Knowledge Construction with mobile devices such as tablet computer, etc. These new teaching methods not only promote students' learning and understanding but also improve qualities of instruction.

- Flipped teaching
  Flipped teaching transforms the teaching process of traditional classroom. Students study after class, and teachers make full use of time in class to provide guidance to every student. It improves the efficiency of class for the videos of before class are the essences limited in 5–7 min. It also promotes teacher paying more attention to students, improving their professional development as well as improving the quality of teaching.
- Teaching by tablet computer
  Teaching by tablet computer not only enables students to learn at anytime and anywhere, but also improves learning efficiency and exercises the students' ability of self-regulated learning. Embedded resources to students' tablets can reduce preparing time and improve students' learning interest, thus improve the teaching quality.
- ICT-based knowledge construction
  ICT-based knowledge construction can enhance the classroom efficiency. It makes each student can raise their own views and opinions online and have more interaction between the students. Teachers can also provide the targeted guidance to the problem and it can help to improve the efficiency of the courses and the teaching quality.

(3) Cultivating Creative Ability

Cultivating creative ability is the most urgent task of education in the social transformation. Social transformation is the transition process from traditional to modern in which social economic structure, people's behavior and value system may change obviously. Education as a social activity aimed to cultivate people should meet with the requirements of the society and promote the socialization of people. As China transformed from a planned economy to market economy, the transformation of economic structure caused the transformation of social structure. The cultivation of creative ability has become the most urgent task in twenty-first century in China. In the aspect of basic education, the teaching goals of some innovative instruction practice had already begun to transform from imparting knowledge to cultivating ability in China, for instance, Maker Education, robot activity, competency-based learning, problem-based learning, etc. Through the cultivation of creative ability, we can arouse students' creative consciousness, cultivate students' creative spirits and improve students' creative ability. It can also make students become the creative talents in the twenty-first century and promote education reform and social transformation.

- Maker Education
  The Maker Movement is a technological and creative revolution underway around the world. Maker Education is a new way of cultivating creative ability. Under the guidance of teachers, students find problems in daily life and do some designs, creations and hands-on operations. Students can solve the problems by completing works. In this way, it not only improves students' learning interest, cultivates students' abilities of finding and solving problems, and the most important is that it can cultivate students' creativity.
- Motivate Educational Approach
  Motivate Educational Approach such as Robot teaching activity is a kind of education activity which based on ICT and higher than the ability of ICT. It can come into contact with a panoramic view of ICT. Through the completion of works and the organization of competition, it improves students' interest effectively and boosts students' learning motivation.
- Competency-based Learning
  Competency-based learning develops knowledge-connected teaching model by integrating multidisciplinary contents. It is helpful to cultivate students' comprehensive abilities systematically. According to development rules of student, it analyzes the inner link of multidisciplinary knowledge system and provides learning activities which needed the application of advanced cognitive thinking for students in problem-solving mode to promote the development of students' innovative ability.

2.5.2 Influence Factors of Innovative Diffusion

Innovation is the focus of education. The development process of innovative instruction may be affected by many factors. Such as education institutions or enterprises supported by government, the school itself, technical innovation and the education demand, etc. Due to the particularity of China's national conditions, government plays an important promoting role in educational innovation. But the cooperation between education research institutions and enterprises can make a big influence on educational innovative diffusion. In schools, the experiment teams need to consider their own school equipment's technical conditions and education needs, and should ask external forces for help actively. The influence factors of educational innovation diffusion also include innovation of technologies and educational demands. It affects the government's policy orientation and provides the direction of researchers and experiment teams, as shown in the Fig. 2.5.

(1) Government-supported Educational Institutions and Enterprise

Government-supported educational institutions cooperate with enterprises to promote the development of educational equity. ICT in education is an effective means to promote educational equity and improve educational quality. ICT in education can spread high-quality digital educational resources to rural and remote areas quickly and easily at lower cost and achieve the sharing of high-quality educational resources quickly. Supplemented by the corresponding management measures, it can improve teaching standards in rural areas in a short time at a low investment. And it can narrow the educational gap of different regions, urban and rural or different schools and promote educational equity and improve educational quality.

Government plays different roles in the educational innovation, including acting as policymaker, facilitator and coordinator. Government plays an important role in innovative instruction system. It is an important organizer of educational innovation.

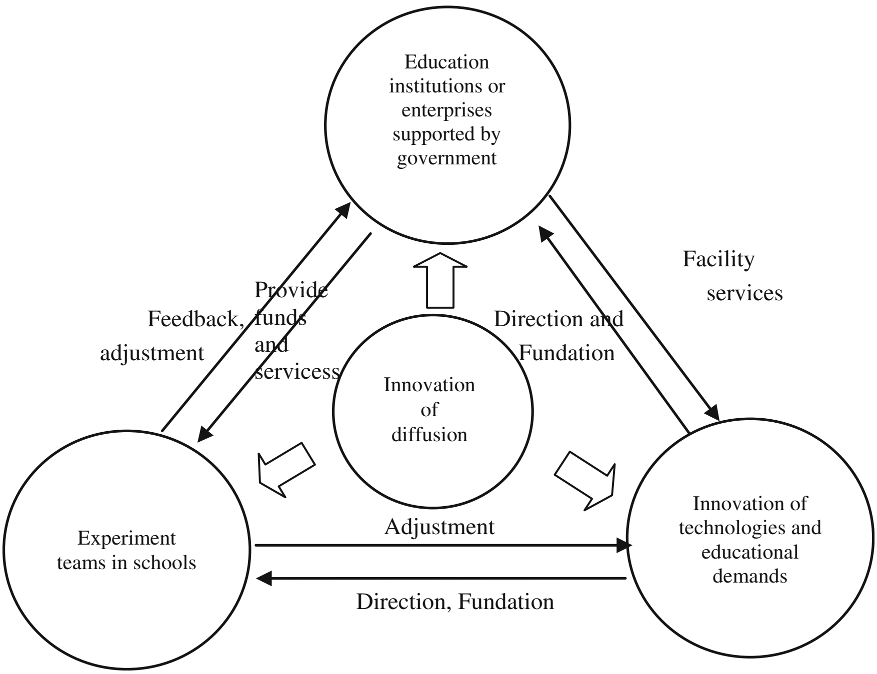


Fig. 2.5 Influence factors of innovative diffusion

There are fundamental assurances of the successful implementation of educational innovation in world's leading innovative countries and regions such as clarifying main responsibilities of government in the implementation of educational innovation, establishing the leading role of government and developing policies, regulations and institutions in order to ensure the well operation of the educational innovation.

It is important to provide educational services and learning support services, which is the key to the successful implementation of distance education in elementary and secondary schools and even more crucial than the learning support services for higher education. Therefore, the operation of model requires specialized agencies or organizations to provide teaching and learning support services. The enterprise has some abilities to provide the teaching services and can take the advantages of their provision of user services and management of customer relationships.

The live-transmission classroom of case one is mainly advanced by Chengdu No. 7 Secondary School, remote schools and Oriental Scent Company trilateral cooperation. Chengdu No. 7 Secondary School is mainly responsible for providing instruction and resources, Oriental Scent Company is mainly responsible for the market and supportive services, and remote schools are mainly responsible for running of live-transmission classroom in their schools and management of students and they are also providing the support for students' learning. In the service of live-transmission teaching, the school is responsible for teaching input, teaching activities and management and Oriental Scent Company is responsible for the investment of equipment and technology and the management activities. The main functions of remote schools' teachers in the "four-in-one" mode are: preparing lessons earnestly and make full preparation for teaching; cooperating with the teacher actively in the class, managing classroom and assisting teaching to show the specific "double-teachers effect" of the teaching in network by multimedia demonstration class; completing the homework correction and after-school tutoring for students. This model can achieve the construction of teachers' community of practice and it can take their own advantages of the three parties of cooperation. It also combines with their respective needs closely. This kind of cooperation model can motivate participants' abilities and improve the effect of cooperation.

Now only a few schools' conditions can support the implementation of flipped teaching, a lot of schools' teaching conditions such as technology, funds, management are not enough to support the implementation of a large-scale flipped teaching. So the large-scale promotion of flipped teaching needs to wait for the right time, thus we should strengthen cooperation with the third-party companies. The flipped teaching of case two cooperates with a third-party company to develop the "Sunshine Micro-lecture" platform based on network environment. In this case, the company freely provides 240 customized tablet computers according to the experiment and then students use their own portable terminals for self-directed learning. This not only achieves the implementation of platform for the flipped teaching, and it also provides technical supports and service guarantee continually.

This kind of cooperation is the foundation of schools to carry out flipped teaching smoothly.

So, departments of government should establish a management mechanism of collaboration and schools should strengthen the cooperation with companies. In the aspect of organization and management, government departments should take the responsibility for clearing the development direction and promoting overall plan and coordination. It is necessary to establish a "multi-stakeholder" operation mechanism of ICT-based the construction of education. The government should explore and form the arrangement of social parties to participate in education ICT-based system, arouse the enthusiasm of participation in education ICT-based and take advantage of market allocation and professional services of some institutions. The resources and funds of schools are limited, the government and enterprises should provide appropriate supports and help them.

(2) The Experimental Team in School

The experimental teams in school with external forces for help actively is one of the influence factors of educational innovative diffusion. Promoting an innovative activity in a school without any experiments is a risky behavior. Through the establishment of experimental teams, school can conduct teaching experiments in some subjects or some classes. In this way, the school can try ICT-based teaching innovations and make comparison with traditional teaching modes and experiencing the advantages of ICT-based teaching.

The experimental team should be guided by the leader teachers who should play the role of opinion leaders. Interpersonal relationship channels are more effective to form and change the innovative concept of individual and it will affect individual adoption or reject innovation decisions. Most individuals do not evaluate an innovative activity by the conclusions which are drawn from the experts' scientific researches, but evaluate the activity according to the subjective evaluations of their companions who adopted it. This is because that these companions played an exemplary role, other members will imitate their innovative behavior. Although the opinion leaders in innovative diffusion are not the people who own the right for decisions such as school leaders, they have high prestige in fellow teachers. If the models lead well, it will be conductive to the rapid diffusion of innovation.

School experimental team also needs to get the help of external forces on scientific and effective supports. For instance, schools can cooperate with colleges and research teams. In the case 6, the school cooperates with the information and technology institution of Northeast Normal University in 2005. In their cooperation, they experienced three phase, namely: initial attempts, reflection and adjustment, and innovation and development. The school uses resources to explore effective application methods of instruction and get scientific and effective support by this institution. Supported by the institution, the school established a leader group and had taken on national and provincial instructional research projects. They had cooperated by introducing synchronous classroom teaching resources, teaching training, experiment guides. In case 8, the school conducted an educational scientific research under the guidance of Dr. Chen Jingping who graduated from State University of New York in the United States in the autumn of 2010 (Li 2014).

The research required students to use the "knowledge forum" and conduct constructive knowledge learning and assessment in order to form a knowledge forum community where students can share and grow together. In this case, the scientific guidance promotes the innovative teaching methods conducted in the school smoothly. In the case 2, from summer vacation of 2013, the school organized some outstanding teachers into lead-organization team to make teaching plans. They worked out all teaching plans for different grades and made them become teaching resources in order to prepare for the implement of flipped teaching. In the case of Maker Education, for the limit of the documents and measures in the aspect of government and policies, the school of case four gathered a group of front-line teachers who are interested in conducting Maker Education set up the Maker Space. They explored how to build the Maker Space and conduct Maker Education in the existing conditions and search for help and develop positively in national scale.

Therefore, in order to generalize new ICT-based teaching methods we need to form experiment teams and through the core team to explore teaching organizational methods and efficient teaching models under different conditions of ICT and get external help actively. Research institutions can provide academic help and support, and enterprises can help the achievements in the direction of technology. Through the core team and external forces, it can explore the ICT-based education formation and application way with characteristics of the school itself and popularize it gradually.

(3) Technological Innovation and Educational Needs

- Technology drives the application

The continuous development of ICT and the emergency of new technologies expand the teaching and learning methods and scope, teachers and students have equal status to access information and it helps to build the new educational model which teachers and students interact actively. The depth and extensive use of ICT will change teaching mode and study style in existence. It makes the education transformed from teacher-centered to student-centered, from knowledge-transfer to ability and quality training and transformed from classroom study to learn from a variety of ways. Education will meet the demand of students and even the diverse and personal requirements of teachers better. Education will be more likely to reflect the basic requirement of morality education and achieve cultivation-orientation, priority of moral education, focus on ability and comprehensive development and it will try to provide appropriate education for each student and enable every child to be a useful person. In the case 5, the headmaster Wangrui thinks that mobile Internet technology breakthroughs constantly and tablets will be widely used; we should make full use of the ICT-based advantage, solve the problem that students' schoolwork are too much in current and change the traditional classroom mode. In September 2011, the school started to establish the ICT-based innovation class. They use mobile and tablet technology, explore the personalized teaching and reduce the burden of learning to promote students' innovative thinking and quality cultivating. The robot course of the school in case three uses robots at the ICT ideal teaching tools. The content of robot course covers sense and control technology. Through teaching practice of intelligent robots, teachers have a new understanding of the connotation of ICT education and it drives the application of ICT-based equipment in teaching.

The progress of ICT causes a major reform in education and the traditional education and management ways are impacted a lot. The emergency of ICT leads educational model in modern transformed from the traditional educational model of classroom teaching to networked open educational mode and improves creative ability of students and teachers with the ICT in teaching innovation. The application of ICT in education is never-ending, the continually innovation of technology provides new methods of application and the new demand of education reforms and developments will also create new applications.

- Demands drive the application

Demand-drives application is the vitality of the development of ICT-based education. For transition of cultivation of talents in the twenty-first century and transition of demand, as well as the problem of our country's resources distribution inequality in currently, governments and schools have adopted a series of measures to improve the quality of teaching, which changed the traditional teaching model. Starting from the goals of teaching and demand of learners we can achieve them through the reform of teaching mode and learning ways. First, we should focus on solving problems in education reform and development and building applications in the field of teaching and learning. This application should be daily activities in teaching and learning which were widely participate by teachers and students, it should provide service of the whole process of teaching activities and it should transform and improve the existing teaching methods. Second, we should put forward and achieve new applications in the process of education reform and development continually. The remote schools in the case one have relatively small number of high-quality education resources due to the lack of teachers, and these schools need more and better education resources. Through the use of advanced ICT means, they cooperated with the school and built synchronous classroom. In this way, they achieve the sharing of high-quality resources and boost the development of education in the poor areas. The emergence of network-based evaluation system in case seven is because of low efficiencies and high cost of process including traditional academic lectures weeks, problems feedback, submissions and guidance of small thesis, interview activities and team cooperation examinations. Therefore, developing this network-based evaluation system to realize the automation of the process above not only reduce the cost, but also improve the efficiency of the evaluation at the same time.

Because of the particularity of China's national conditions, government plays the most important role in organization and implementation. In modern society, the primary responsibility for holding and initiating social welfare undertakings and public undertakings lies with the government. But even the government has its own holdbacks and it is often powerless to deal with many problems. Including research institutions and practitioners play different roles in educational innovative diffusion.

2.6 Discussion

Owing to the particularity of Chinese national conditions, government plays the most important role in organization and implementation. In modern society, the primary responsibility for holding and initiating social welfare undertakings and public undertakings lies with the government. But even the government has its own holdbacks and it is often powerless to deal with many problems. Including research institutions and practitioners, play different roles in educational innovation diffusion.

2.6.1 The Focus Point of Government, Scientific Research Institutions, and Practitioners in Education

Government, scientific research institutions, and practitioners play different roles in educational innovation diffusion. By the informatization of education, the government can quickly and easily disseminate high-quality digital education resources to rural and remote areas at a lower cost and can achieve the goal of sharing high quality education resource in a short time, combing with the corresponding management measures. Teaching standard of school in rural areas can be improved in a short period of time with a small amount of financial investment. The educational gap between urban and rural areas and between different schools can be narrowed, even promote education equity and quality. Research institutions promote the further application of new theory and technology and play a supporting role in schools, which can develop students' creative ability. Practitioners can effectively promote the improvement of the quality of education, because practitioners are the real workers. Schools and teachers should take effort to help student to acquire knowledge, develop moral ability, etc., and by means of original and scientific teaching methods and various teaching modes the students can learn how to communicate, make dialogues and cooperate in interactive practice. Education quality needs to be improved by optimizing the management system or training teachers. As mentioned above, the problems about education fairness, education quality, and student's creative ability can be solved by these eight innovative instruction practices. Because of the different goals, the main focus of government, research institutions, and practitioners in the problems of education fairness, education quality, and student's creative ability are different (Table 2.4).

Table 2.4 The focus level of government, research institutions and practitioners in the problems of teaching fairness, teaching quality, and student's creative ability

	Education fairness	Education quality	Student's creative ability
Government	High	Medium	Low
Research institutions	Low	Medium	High
Practitioners	Medium	High	Low

The perspective government focuses more on educational equality and also pays attention to educational quality. Increasing government educational investment is an important prerequisite for narrowing the gap between regions and schools, and is the key to promote educational equality. In longer term, if education investment is not increased, only changing the distribution model of the existing educational resources results in sacrificing the quality of local schools to achieve education equality. Or in the way to industrialization, the government is responsible for weak schools' education development and market is responsible for quality schools' education development, which cannot achieve the goal of education fairness development. Increasing government investment in education, especially in rural areas, less developed areas, K12 schools, to help them afford teacher's salary and let every child go to school and enjoy equal opportunities and educational conditions. Chinese government should keep disseminating public educational resources to rural areas, the central and western regions, the frontier regions and the minority regions. The government should gradually narrow the education development gap between urban and rural areas and between different regions, coordinating the pace of the development of public education. The education funding system and the education management system should be improved and the allocation of high quality education resources should be balanced. The government should take effort to optimize the allocation model to avoid the education gap caused by the differences in regional development. As to the educational opportunities, the government should provide the compulsory education opportunity to everyone, pay attention to the unbalanced development of regional education, and reveal individual equality and education fairness.

Research institutions are mainly focused on the cultivation of students' ability. The instruction under research institution's support is based on the idea of adapting to the new curriculum, innovative education model. The teaching suggestions are raised from the perspective of theoretical to promote students' comprehensive and sustainable development. Meanwhile, scientific researchers pay more attention to the cultivation of students' learning ability to meet the needs of their own and social development. Under the background of basic educational curriculum reform and student subjectivity's importance being increasingly advocated, the research institutions explore pertinently the practical patterns to bring students' subjectivity into full play, and embody students' individuality to make them actively and widely acquire knowledge.

Practitioner's main focus is the improvement of education quality, which is an important guarantee for the development of education requiring the efforts of all stakeholder including both teachers and leaders. The teaching quality means everything to a school, and improving the education quality is the main reason and final goal to each school's development. School management, moral education, and education teaching research, or building teachers' team, all need to focus on how to improve education quality. Teachers should combine their own development with social requirements, constantly update their knowledge structure, and arme themselves with new educational ideas to meet the requirements of the new curriculum reform. A solid foundation of the teachers is the prerequisite to improve their ability, especially the ability to control the comprehensive problems and open questions. During daily teaching process, the teachers should be accordant with the requirements of the new curriculum standards, tamp foundation, and strengthen application. The teacher's idea of cultivating students' awareness and initiative need to be guided, while students' questioning ability and consciousness of participation need to be motivated. Through rigorous training, let student form a habits of hardworking, meticulosity, and elaborate, and enhance students' participation consciousness and questioning ability.

2.6.2 Typical Model of Education Innovative Diffusion in China

Governments can take different roles in innovation, from creating favorable conditions to foster leaders of innovation. They often take several roles at the same time, depending on their needs and the political interest in promoting innovation in the area in question. The policy recommendations cover all of these potential roles.

National policy documents that support the use of innovative teaching and learning exist in all countries and most countries reported some national-level program support for innovative teaching and learning.

The promotion of the Chinese government is an important driving force of the development of ICT in education. In the centralization model, the national government leads and guides the development process of ICT in education in Mainland China by providing financial support, policy guidance, project monitoring, management, evaluation, and other measures. From the perspective of effective implementation, the most distinguished characteristics of the state-driven approach are the speed, the broad coverage, and the operation by the administrative system.

Since the late 1970s, the modernization drive, the reform, and opening up to the outside world have transformed China's highly centralized planning economy into a market-oriented and a more dynamic economy. Acknowledging that over-centralization and stringent rules would kill the initiatives and enthusiasm of local education institutions, the national central government called for resolute steps in streamline administration and to devolve powers to units at lower levels so as to allow them more flexibily to provide education. Nowadays, the socialist state in China is transforming into an accelerationist state, with a neo mercantilist character, since the government is heavily involved in "market creation" and officials actively use their policy capacities to create, enhance, and maintain the "governed market" or "state-guided market" in China (Mok 2005).

The Diffusion of Innovation model of Rogers (1995) is concerned about planning and guiding organizational change processes to promote the adoption of new innovations. Understanding how early adopters will push organizational uptake of new products and processes, or how entrenched resistors or "persistent skeptics" can stonewall change, is important for change managers and will help to scale-up the innovation of ICT in education.

There are two diffusion systems (models) in society: centralized and decentralized models (Rogers 1995). The former is a classical diffusion model, spreading from a central source of innovation to the adopters; the latter, by contrast, means that innovation may not come from the formal research and development system, but often emerges at the operational level within the system through invention by some major users of the system. The decentralized diffusion model is constant with recent literature on diffusion of educational innovations (Developmental Education Task Force 2008; Bye et al. 2013). In the scale-up of innovative ICT in education, those two types of diffusion system are in co-existence. We call the centralized model as Researcher-Led Diffusion of ICT in Education (shown in Fig. 2.6), and the decentralized model as Practitioner-Led Diffusion of ICT in Education (Zhang 2009a)

The centralization diffusion system (Researcher-Led Diffusion of ICT in Education) is based on relatively linear, top down, and one-way communication. Due to the long-term effects of the traditional educational model, the high pressure of enrollment and academic performance and the generally poor learning environments of the schools, educators including teachers, administrators of school, or regional education organization have no time to work on the new methods, technology, and applications. Therefore, Chinese educational organizations highly rely on researchers as experts to design and develop the innovations. The source of innovation is derived from the technical or educational experts in the field of ICT in education. In the research community, through multiple channels, researchers create or recognize the innovations that are worth promoting and proliferating to the practitioners. Acting as innovation agents, researchers inform the policymakers and practitioners. Policymakers evaluate the value of the innovation, judge the feasibility of diffusion, control the funding (increased or reduced) by monitoring the diffusion process once they make the decision to promote, guide research community activities, or release new policy and regulations (such as incentive policies)

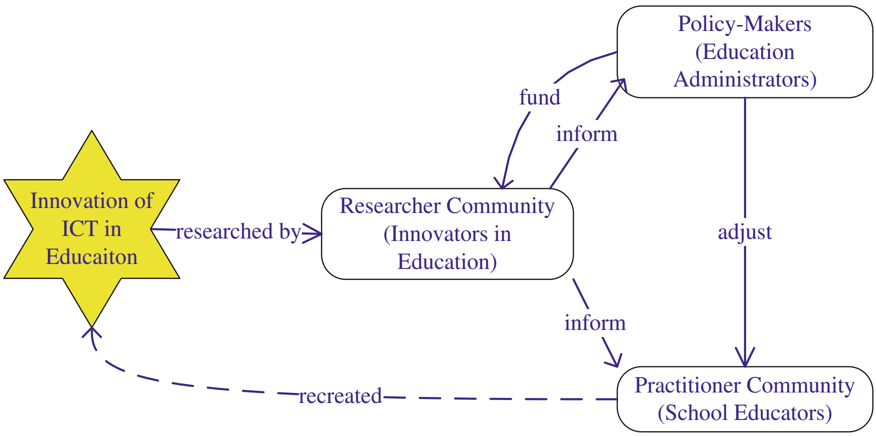


Fig. 2.6 Researcher-led diffusion of ICT in education

guiding practitioners' participation. In the process of adopting, implementing, and spreading the innovations, practitioners can also recreate or improve the innovation, thereby looping back to inform the next cycle of research.

The innovative diffusion in the perspective of practitioners, on one hand is the school level; on the other hand is the teacher level. There are two main types of school education innovation, one of them is the educational technology diffusion project mode that school actively seek external help, it is a typical "problem-solving mode." In this mode, the initiator of technology diffusion is school; after the assessment of what they need, the problem that urgently need to be solved is identified, get support from innovative institutions through seeking help from outside. Innovative institutions analysis the needs of schools, develop or select a certain innovative educational technology products for schools, achieve promotion in a large scale after a small scale of trial and modification; during the period of trial, innovation institutions may also provide support (Fig. 2.7).

In the process of the promotion, schools should establish innovative diffusion promotion team and put a key person in charge, this team should include a director in teaching and research section, technical support personnel, experiment teacher, etc. Continuously promote internal experimental activities and the relationship with external through frequently internal communication. The team has a strong spontaneity and autonomy, therefore can do a great job in promoting the project. First, the innovative diffusion promotion team gets support from the school by regularly reporting to the school leaders; second, when facing the problems in the experiment, the director in teaching and research section should seek help from innovation institutions; third, advertising and providing support to other teachers (Fig. 2.8).

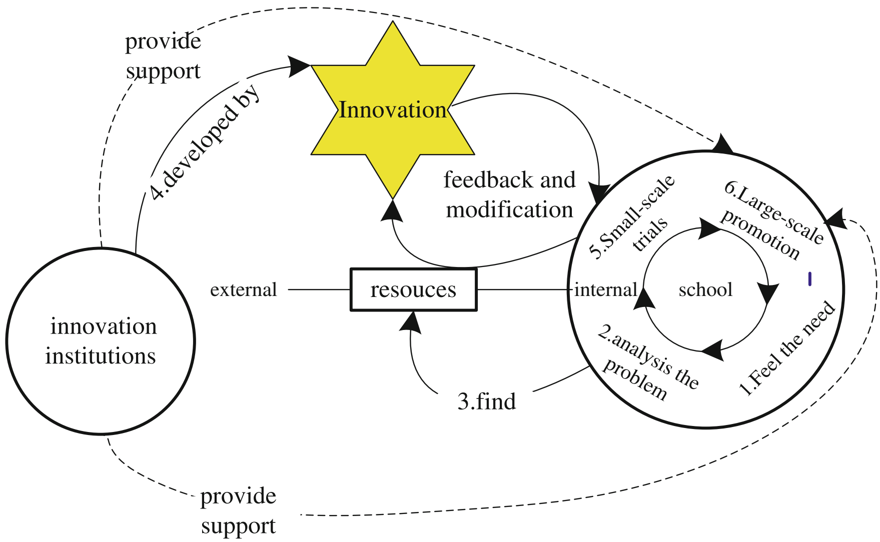


Fig. 2.7 School actively seek external help in the educational technology diffusion project mode

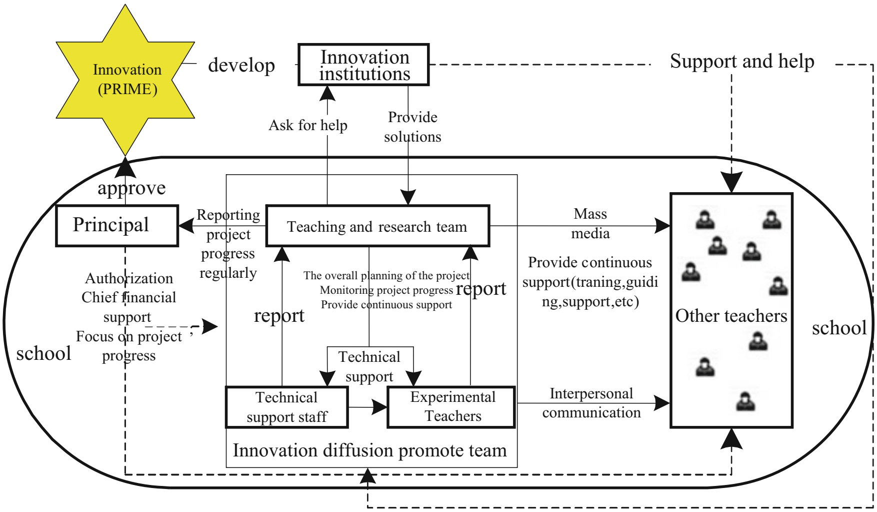
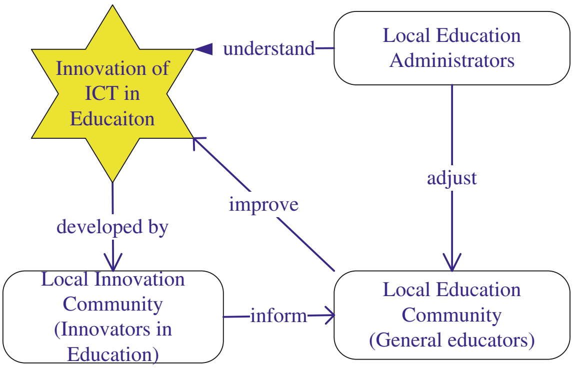


Fig. 2.8 The basic mode of innovation diffusion promotion team in promoting educational technology experiment

Innovative teaching happens more in environments where teachers have access to strong programs of professional development. In professional development, both intensity and design make a difference. Survey data show that innovative instructional practices tend to be reported more frequently by teachers whose recent professional development has been longer term and included more hand-on activities, such as practicing teaching methods and conducting research rather than observing demonstrations and listening to lectures.

The decentralized model as practitioner-led diffusion of ICT in Education (shown in Fig. 2.9). Compared with the centralization diffusion system (Research-Led Diffusion of ICT in Education), the decentralization system of innovation can better meet the needs of users, and help address their problems. In this decentralization system, users are able to feel the sense of ownership and

Fig. 2.9 Practitioner-led diffusion of ICT in education



control of the innovation, because they are in the center of the key decisions. For example, educators can decide which problems should be paid prioritiy for attention and be resolved, what innovation can best meet their needs, from where and how to obtain the relevant information, and how to make appropriate amendments once implementing innovations in specific circumstances.

2.7 Conclusions

In the twenty-first century, the position of the job is more inclined to the talented person who has more creative, critical thinking, ability of solving the problems, and the ability of taking decisions. Furthermore, the workers in the twenty-first century should adopt the way of communication and cooperation. The workers must possess the information literacy. Therefore, teaching practice need to continue exploring and studying to transform the traditional teaching mode to break through the education barriers. There are already a bunch of good samples in instructional innovation practice in China, but the experience and the diffusion mechanism need to be summed up in order to achieve educational innovation on a larger scale. To promote educational innovation, government, schools, and practitioner need to promote the education and teaching innovation mechanism. Education reform is a systematic work, which needs a better communication between governments, fields in education, business community, and social groups. And the goal of education should meet demand of both personal and social development, by using social resources effectively, and pursuing reforms under a circumstance of coordination. It also needs a series of concrete steps to conduct, such as reform standards and evaluation, curriculum and teaching, teacher professional development and learning environment, etc. These factors constitute a guaranteed system; and the relationship between them is indivisible and interdependent, which means the neglect of any one can restrict the integral effect. Therefore, the consistency and synchronization between the various segments must be guaranteed in order to make contribution to the development of education innovation in China.

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Part II
Methods to Design Learning

Chapter 3
Instructional Design Methods and Practice

Issues Involving ICT in a Global Context

Jonathan Michael Spector

Abstract The rapid introduction of powerful digital technologies in the last 20 years has made it possible to create innovative and engaging learning activities in nearly every subject domain at nearly every education level. As a consequence, however, the task of designing, developing, and deploying effective instruction has become ever more challenging. While the basic instructional planning competencies and skills remain about the same, the emphasis in instructional design has shifted to the technologies used to support specific learning goals and objectives. This shift in emphasis has had consequences that have yet to be properly addressed. For example, the prior emphasis in the instructional design community on evaluation and empirical research has declined while there has been increasing emphasis on innovation and specific technologies. Doctoral programs in instructional design have also experienced a shift in emphasis from research and scholarship to development and practice. Overall, instructional design is becoming more and more a craft industry and less and less a scientific enterprise. These generalizations might be overstated but they raise concerns with regard to how best to link together the design of instruction, educational research, and the deployment of technologies aimed at improving learning, performance, and instruction. This chapter presents an elaboration of these claims and a possible path to resolution that builds on emphasizing formative evaluation and fidelity of implementation studies.

Keywords Fidelity of implementation · Instructional design · Learning activities · Program evaluation · Replication studies · Technology integration

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3.1 Introduction

It is widely accepted that new digital technologies, including mobile applications and cloud-based resources, have the potential to significantly improve learning, technology, and instruction (Huang et al. 2013; Ifenthaler et al. 2011; Sampson et al. 2013). As a result of a plethora of new and powerful technologies, the task of designing, developing, and deploying effective learning environments and instructional systems has grown increasingly challenging and complex (Merrill 2013; Spector 2012; Spector and Merrill 2008). The argument presented herein is that it becomes increasingly important to conduct systematic evaluation of studies and ongoing research with regard to the use of technology in support of learning, performance, and instruction. However, there is a great deal emphasis on the attributes of specific technologies in the research and popular literature and too little emphasis on research linking with the use of those technologies in designing learning activities, lessons, and curricula and the sustained learning and performance outcomes achieved on a significant scale (Spector et al. 2015).

In addition, the preparation and professional development of those responsible for planning and implementing advanced learning technologies have increasingly focused on the operational aspects of specific technologies rather than on evidence-based issues pertaining to systematic and sustained improvement in outcomes (Spector 2015a). Much of the research that is published tends to report case studies and the perceptions of those involved with these technologies (Reeves and Reeves 2015; Spector and Merrill 2008). The remainder of this chapter is an elaboration of this multidimensional problem along with a discussion of potential remedies.

3.1.1 Definitions

So as to minimize ambiguity and misunderstanding, the following definitions apply to the key terms involved in this chapter:

- *Educational research*—the exploration of factors (e.g., cognition, individual attributes, learning activities, lessons, curricula, organizational characteristics, etc.) that influence learning and instruction; descriptive, explanatory, or predictive research that applies to both formal and informal learning that occurs over an individual's lifetime, or across a group of individuals, that is aimed at improving desired and valued outcomes in a systematic and sustained manner (see Creswell 2011).
- *Fidelity of implementation*—A kind of formative evaluation of projects and programs that closely examines the goals, objectives, and specifications for an effort so as to relate how well an effort has been implemented with the degree to which goals and objectives are attained (see O'Donnell 2008).

- *Instructional design*—the practice, methods, and processes associated with planning, implementing, and evaluating effective learning and training (see, for example, Richey et al. 2011; Spector 2012; see also www.ibstpi.org).
- *Learning activities*—an activity designed and organized with the intention of improving attitudes, competence, knowledge, or skills; learning activities have an explicit or implicit (the former is preferred) purpose and are designed, organized, and structured in a manner likely to fulfill that purpose (see European Communities 2006).
- *Program evaluation*—systematic and structured methods and processes aimed at determining how well a project or program has been implemented and to what extent intended outcomes have been achieved; program evaluations are typically mixed methods of research efforts that should be matched to type and status of an effort (see Hamilton and Feldman 2014).
- *Replication studies*—purposeful repetitions of prior studies in order to confirm or disconfirm findings or to identify issues and limits to generalization; replication studies are rarely exact duplication of prior studies; a replication study is usually aimed at testing the same or similar hypotheses and constructs of a prior study using the same of similar instruments with a somewhat different or larger group of participants (see Makel and Plucker 2014; Spector et al. 2015).
- *Technology integration*—the use of technology to create meaningful and effective learning and training experiences (see Merrill 2013; Mishra and Koehler 2006; see also http://tech.ed.gov/netp/).

When one keeps definitions clearly in mind, it is possible to minimize ambiguity and distractions that inhibit a focus on improving a problematic situation. In this case, the problematic situation is that we have many more powerful learning technologies available than ever before (Spector 2001, 2012). That makes it particularly challenging to prepare and train educational technologists as well as creating an urgent need for strong evidence with regard to which uses of various kinds of technologies, with a variety of learners in different situations, are likely to be effective and efficient and why. This chapter will perhaps take one small step in framing these challenges and suggesting directions for the next few steps.

3.2 New and Emerging Technologies

In Act 1, Scene V of *Hamlet*, Shakespeare has Hamlet say to his friend Horatio that there are more things in heaven and on earth than one can dream or imagine. The context in that fictional case involves a ghost. However, the notion that the world is not constrained by one's imagination can be regarded as one foundation of research and evaluation. In different words, one may know less than one believes that one knows with regard to nearly any complex problem, question, or subject. The reason for conducting evaluations and research is to gather more evidence that may potentially change one's beliefs.

In the context of a new educational technology, it is not uncommon for one to become fascinated with possibilities to improve learning and, as a result, become an ardent advocate of a particular technology. The issue of being overly enamored with a technology has been debated by Clark (1994, 2007) and Kozma (1994) among others. What seems clear from those discussions is that it is how new technologies and media are used that is likely to have an impact on learning and performance (Ge, Ifenthaler, and Spector, in press).

What, then, are the types of new learning technologies and what affordances and uses should be considered by designers and instructors? There are many ways to develop a classification of learning technologies. Dimensions of a learning technology taxonomy might include, for example, (a) targeted users, (b) goals and objectives supported, (c) aspects of the instructional situation, (d) media involved, (e) time and space considerations, and so on. To keep the discussion somewhat constrained and focused on evaluation, research, and professional development, three broad (and somewhat overlapping) categories are discussed next: (a) adaptive technologies, (b) mobile applications, and (c) social media.

3.2.1 Adaptive Technologies

An adaptive learning technology is one that automatically adjusts to individual users as they interact with a learning environment or instructional system. An intelligent tutoring system (ITS; see Psotka and Mutter 1988) is a prominent example of an adaptive learning technology. An ITS has internal representations of the knowledge domain and an instructional strategy (sequencing of resources and activities) along with likely misconceptions and errors that a learner is likely to make as he or she progresses through the lesson or course. Depending on the learner's progress, the system selects appropriate resources and activities, thereby adapting to the needs of a particular learner.

Creating and maintaining dynamic student profiles that include not only student progress but specific characteristics and interests of individual students has advanced since the 1980s so that learning systems can be adaptive not only with regard to the content mastered but to other aspects of a learner, including a learner's optimal learning style (Graf and Kinshuk 2013). When such considerations are taken into account, the system does not need to find appropriate resources and activities, those resources and activities need to be customized so as to be meaningful for a particular learner. Such customization is a nontrivial task, as it involves the representation of information as well as examples used, formats, and specific interactions. Among relevant individual characteristics are disabilities that need to be taken into account by an adaptive learning system.

Learning analytics involves mining large data sets involving a wide variety of learners and learning activities along with related learning goals and objectives and information about the success of various learners (and their profiles) when engaging with specific resources and activities (Slade and Prinsloo 2013). It is clear that the technology to support such an application of learning analytics in a learning environment or an instructional system exists. However, for a variety of reasons, including companies unwilling to share access to information considered proprietary and public, determine to preserve the privacy of individuals, the large-scale application of learning analytics, dynamic student profiling, and advanced ITS technology have yet to be fully realized (Spector 2014b).

3.2.2 Mobile Applications

Mobile learning applications (a.k.a., apps) include those which are designed to be used on tablet and handheld devices. Due to explosion of mobile apps, the term 'm-learning' is now surpassing the use of 'e-learning' in many cases, in part because e-learning has become so ubiquitous that nearly every learning environment and instructional system is making use of electronic and Internet resources. As a result, some have argued that 'e-learning' really should stand for engaging, effective, and efficient learning (Spector and Merrill 2008).

Meanwhile, mobile learning is now spreading the way that e-learning spread some 10 years ago. It is worth noting that similar phenomenon is occurring with m-learning that happened with e-learning. Mobile apps are making their way into school-based environments, through the spread of bring-your-own-device (BYOD) policies. In some places, there is a great deal of resistance to BYOD, due in part to concerns about equity, cheating, pornography, and so on. However, the notion of a hybrid learning environment that included both residential or face-to-face learning as well as Internet-based activities now includes activities that can be conducted in or outside a formal classroom setting using mobile devices.

The potential of having near real-time access to resources is clear. However, not everything that a student can find quickly is going to be reliable. Moreover, the issue of equity is real. Not all students have smartphone or access to the Internet using a mobile device. The digital divide can easily and quickly grow much worse than it already is. In addition, the spread of misinformation and propaganda can also be accomplished more efficiently and quickly than ever before.

The affordances of mobile apps are nonetheless significant. There are already many free and reliable resources that can be used on a mobile device. For example, the Khan Academy (https://www.khanacademy.org/) is widely recognized as an important resource in mathematics and other areas. Instructors can integrate those resources in a flipped classroom environment by assigning students to view and use Khan Academy resources outside class and then use classroom time for practice, development, and reflective discussion. While the Khan Academy is considered by some to represent a MOOC (massive open online course), it can be transformed into an effective mobile open online community (see Spector 2014a). However, that transformation requires significant training of teachers and instructional designers, which is discussed later.

It is also worth mentioning that mobile apps can in principle be linked with adaptive technologies. Including learning analytics in mobile apps has the potential to significantly impact learning and instruction, although there is as yet no such large-scale trials and evidence to support that claim.

3.2.3 Social Media

As with mobile technologies, there has been extensive growth in the area of social media in the last 10 years. Specific social media technologies have come and gone, but several remain stronger than ever before (e.g., Facebook, LinkedIn, Flickr, Instagram, etc.), and new forms have arisen in the form of microblogging and apps aimed at a very specific activity (e.g., Twitter, Pinterest, Tumblr, etc.).

These technology-mediated tools use the Internet to share ideas and exchange a variety of resources (information, images, videos, etc.) within a virtual community that may or may not be well defined or delineated. One education use is to support group work. Yet another use is to access remotely located resources, including expertise. Because there are clear uses in support of learning and instruction, it is argued that social media are a critical learning technology. However, when recalling the media debate mentioned previously, it is worth noting that just because a technology exists does not mean that it is well suited for every instructional situation (Tennyson 1994). As is the case with mass media, social media in education can, in some cases, amount to pooling or polling ignorance rather than amounting to progressive and productive learning.

As with other advanced technologies, the fascination the affordance of a new technology and the potential to significant and sustained improvement in learning and instruction can lead to a position of advocacy rather than one of inquiry and research. There are many case studies that serve to reinforce the beliefs of the advocate. There are not many studies that provide evidence that could be used to advance scientific research however (see, for example, Makel and Plucker 2014).

3.3 Designing Learning Environments and Instructional Systems

Given such innovations as adaptive learning, mobile technologies, and social media, the ability to effectively integrate those and other technologies into learning and instruction becomes a challenge (Richey et al 2011; Spector 2012). As previously noted, one challenge is to avoid overuse of a particular approach or technology (Tennyson 1994). There are many other challenges that could be discussed. A major challenge is to maintain clear, consistent, and coherent links between goals and objectives on the one hand and activities and assessments on the other. Doing so enables one to revise and refine interventions as well as develop evidence about what works, when, and why. In this section, three challenges are discussed that are critical for the effective design of instruction: affordances, constraints, and design.

3.3.1 Affordances

The tendency is to start with a consideration of which technologies to use in a lesson, course, or program. This is not an ideal starting, but many informal observations suggest that where many designers and instructors actually begin. A better point of departure in terms of maintaining alignment of goals and objectives with activities is with an analysis of the problem or situation or issue being addressed when designing or redesigning a lesson, course of program (Natividad et al. 2015). All too often, a needs assessment and learning requirements are overlooked or only superficially examined. At best, the symptoms of a problem are taken into consideration, such as a high attrition rate, with too little attention given to the likely underlying causes of the perceived problem symptoms. In any case, the reality is that educational technologies do have a tendency to develop an affinity for particular technologies, in large part based on their affordances.

One likely reason that educational technologists and instructional designers develop affinities for particular technologies is that they have a bias for a particular instructional approach, and, as a consequence, they may have noted that a particular technology is particularly well suited to support that preferred approach. For example, many instructional designers and educational technologies believe that constructivism (see Jonassen 1997) is the right philosophical point of departure; furthermore, they believe in experiential approaches (see Kolb 1984). Such approaches include open-ended inquiry, problem-based learning, and situated learning. More recently, collaborative learning (see Berkeley et al. 2005) has been added to that set of preferred approaches.

Given a decision or preference to support epistemological constructivism and experiential learning to the extent possible, and a belief that a particular technology such as a collaboration tool is well suited for that purpose, an educational technologist or instructional designer may then focus on the various collaboration tools and technologies and look at their particular capabilities and affordances. For example, the tool category being examined might be a wiki. Then specific capabilities of particular wiki tools might be examined to see which ones were open and which ones were restricted, which were contained within another tool, which allowed each inclusion of links, images, and videos, and so on (see http://www.wikimatrix.org/ to pursue this analysis in more detail). However, such an analysis of tool affordances overlooks the link back to the problem being addressed and specific goals and objectives. More capabilities and affordances made possible by a particular tool do not necessarily result in improved learning or instruction. A number of instructional design approaches strongly suggest otherwise. Cognitive apprenticeship (Collins et al. 1987) implies that learners at different levels required different kinds of support. The Four-Component Instructional Design model (van Merriënboer 1997) suggests that supporting learning of recurrent task is quite different and requires a different approach than learning a nonrecurrent task.

The affordances that should be considered are just those that link directly back to specific learning goals and objectives. While that principle seems noncontroversial, it seems not to receive much attention or emphasis in instructional design practice (based on this author's admittedly limited observations). Moreover, it is not strongly emphasized in the research literature, although there are notable exceptions (see Richey et al. 2011).

3.3.2 Constraints

This author has claimed in a number of presentations to have discovered the universal underlying principal of all stuff (UUPS, pronounced 'oops'). That principle is simply this: *something has already gone wrong*. UUPS has three corollaries: (a) mistakes rarely occur in isolation, (b) resources are hardly ever sufficient to do what one believes should be done, and (c) others nearly always have better ideas. What led to this principle was a case of being told what the solution to a particular problem situation was without any supporting analysis or evidence. The particular problem involved researchers not being familiar with the constraints of the federal acquisition regulations in the USA. The solution prescribed was to create computer-based instruction about the regulations. In that case, the regulations frequently changed, the unit being tasked was a research unit and not a design or development unit, and there were available specialists who regularly guided the acquisition process anyway. Fortunately, the unit manager was able to convince higher level decision makers that having that unit create computer-based instruction for that case was not a good idea. What was persuasive was not the inappropriateness of the technology for the problem situation. What was persuasive was that the unit would be taken away from important research priorities.

The second corollary of UUPS speaks directly to the issue of constraints. Recognizing that constraints are not adequate leads to at least two possibilities. One can modify goals and objectives so as to aim at what is actually feasible, or one can abandon the effort. Often, compromise is the better choice if one wishes to make progress. Changing everything all at once is rarely feasible, and adopting a graduated approach with evidence of success collected for each step along the way is likely to be a successful planning strategy.

Cost is one of the most cited constraints associated with introducing a new technology into learning and instruction. However, cost analysis is quite superficial. Typically, only short-term costs are considered, and then those primarily associated directly with the technology itself, overlooking the cost of training and other indirect costs. Maintenance is also frequently overlooked on the cost side. On the benefits side, the ability to quantify potential and likely benefits in terms of costs is a challenge. In the medical domain when a preventive treatment regimen is being introduced, the likely decrease in sick days is typically counted and given an associated cost. In education, how does one calculate the cost-benefit of an increase in the graduation rate or an increase in test scores or an increase in retention in a major? This is an area worth further investigation (Luschei 2014).

3.3.3 Design

In the world of ISD there is a discussion of whether ISD stands for instructional systems design or instructional development (Richey et al. 2011; Spector 2012). There is a parallel discussion of 'big D' or 'little d' for both 'design' and 'development'. Those discussions generally involve the scope of what is considered design or development. Some consider design only to involve analysis and planning and development only to involve prototyping and implementation, for example. Others consider either one to refer to the entire life cycle process involving such interrelated processes as (a) needs assessment and planning analysis, (b) design specifications and feasibility analysis, (c) prototyping and implementation, (d) deployment, (e) management and maintenance, and (f) evaluation and reporting. There is no right or wrong answer so long as the scope is made clear in particular cases. In this discussion, the focus of design is on planning and specifications, which are interpreted herein to include selection and sequencing of instructional approaches, resources, and activities as well as selection of likely representations, settings, and technologies.

Even with the focus on a limited-scope interpretation of 'design' there are many issues requiring different knowledge and expertise to be made (Gibbons 2012). These various design issues and decisions are interconnected and have implications for decisions that arise further downstream when implementation, management, maintenance, and evaluation issues arise. For example, in a design for a specific course involving adaptive learning, the source for information about the interests, preferences, and past performance of learners is a critical factor. That information changes over time and is likely to be used in a variety of other contexts. Having a single source repository that is responsibly maintained is an important consideration. If such a repository does not exist, then part of the design might well involve the creation, management, and maintenance of such a repository. The knowledge and expertise required for that decision are quite different than the knowledge and expertise required to decide what representational format is best suited for a particular learner or which resource is likely to easily understood and clearly relevant to stated objectives.

3.4 Preparing Educational Technologists

Programs in colleges and universities that prepare professional educational technologists and instructional designers have existed for more than 50 years (Spector 2015a). Strong programs have come and gone, and the leaders of the field, who came from a variety of disciplines, are fading into history. How these programs are preparing educational technologists, and is that preparation likely to be adequate in the future, given the many changes in technologies and instructional organizations?

Current programs are typically at the master's or doctoral level, although there has been an effort to introduce undergraduate curricula in advanced learning technologies (Hartley et al. 2010; Spector 2015a). Different programs emphasis different aspects of educational technology and instructional design. Some emphasize technology competence. Others emphasize planning and analysis skills. Still others emphasize research and evaluation. Moreover, many of those responsible for planning, implementing, evaluating, and managing learning environments and instructional systems have little or no formal academic training in educational technology or instructional design.

The UUPS discussion involved a case where a person not at all knowledgeable with regard to educational technology made an ill-advised decision and give an instructional design team an impossible task (which they fortunately managed to avoid). However, it is quite often the case where those making decisions with strong and immediate instructional technology implications have little or no formal training and make those decisions based on the popular literature or the advice of a vendor, consultant, or friend, who might also lack the needed knowledge to provide good advice.

Given that background, the issues with regard to the preparation of educational technologies can then be put into a number of categories, including (a) communication, (b) collaboration, (c) research and evaluation, (d) knowledge about the subject and learning, and, (e) technology knowledge and skills. As Hartley and colleagues (2010) and Spector and Anderson (2000) have argued, educational technology is inherently interdisciplinary. A balanced curriculum should then draw on a number of fields in preparing educational technologies (e.g., computer engineering, educational psychology, human factors, human resource development, information technology, learning science, etc.). However, the tendency is to require few if any courses outside the college or faculty in which the educational technology program is situated.

The International Board of Standards for Training, Performance and Instruction (see www.ibstpi.org) develops sets of standards with competencies for training managers, instructors, instructional designers, evaluators, and online learners. These standards are evidence-based and typically involve large-scale surveys of practitioners and scholars around the world. The one competency routinely rated as most critical in the domains surveyed is *communication*, yet few programs explicitly support the development of the ability to communicate effectively in visual, oral, and written forms.

Because the design, development, and deployment of learning environments and instructional systems involve a team, it would seem reasonable for programs preparing educational technologists to emphasize team skills, such as being an effective team member or team leader. While most programs do require some teamwork, what is typically emphasized is the product developed by the team and not teamwork skills.

Few programs at the master's level, which is the level used to prepare practicing educational technologists, require significant research or evaluation training. As it happens, program evaluation knowledge and skill is in demand in many settings due to the accountability culture that seems to be spreading. However, few educational technology professionals have the required knowledge and skills and, as a result, evaluation is often outsourced or de-emphasized.

As already mentioned, many educational technologists are not driven by educational research or evidence-based learning theory. Rather, they are driven by personal preferences and the constraints within which they must work. Professional educational technologists should be able to communicate effectively relevant learning theory along with the findings of research and related evaluations of technology to institutional decision makers. However, programs seldom prepare them for such responsibilities.

3.5 Advancing Research, Design, and Practice

The argument in this chapter has gradually worked its way to research, design, and practice. As is obvious from the previous discussion, these three enterprises are tightly interconnected. One way to conceptualize the interrelationships is through a logic model (Spector 2015b). In general, a logic model is a visual depiction of how a current state of affairs can (will be or has been) be transformed into a desired state of affairs (see http://www.smartgivers.org/uploads/logicmodelguidepdf.pdf for details on developing a logic model). A generic logic model template is depicted in Fig. 3.1.

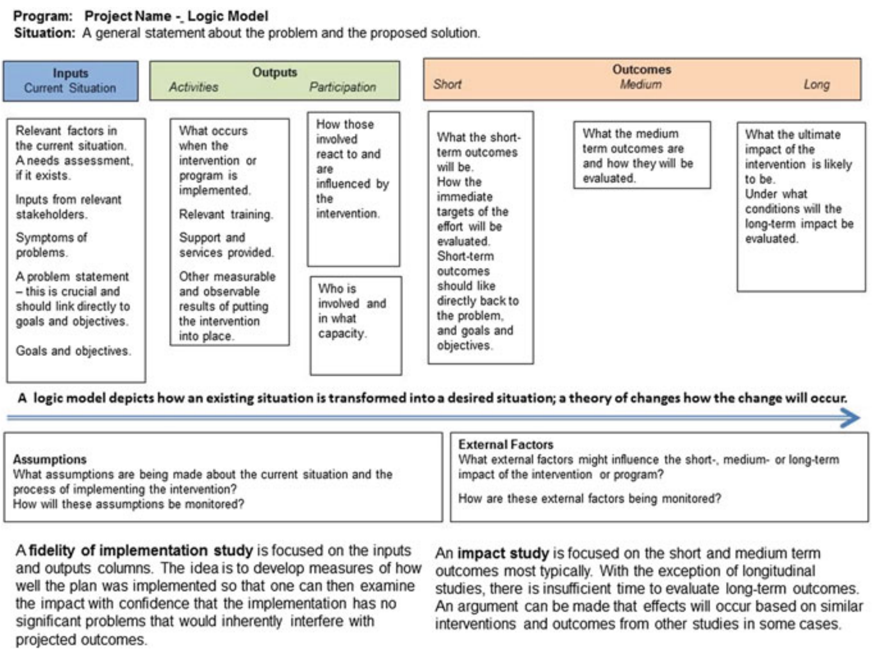

Fig. 3.1 A generic logic model template

While logic models are usually associated with program evaluation (Hamilton and Feldman 2014; Spector 2015b), they are useful in framing a research study as well as in explaining to managers, decision makers, and funding sources what the effort is about and why it is structured the way it is. The *Inputs* column in a logic model depicts the current situation, which could be a perceived problem or simply prerequisites students have had along with their typical knowledge and experience and organization constraints. The *Outputs* column focuses on details of the implementation, based on the goals and objectives established in the Inputs area. The *Outcomes* columns focus on the desired states of affairs after the intervention has occurred or the program put in place. The outcomes should link back to the problem, goals, and objectives in the inputs column. The outputs should also link back to the inputs column as well as linking forward to the outcomes column.

Associated with the logic model is a theory of change that explains why one should belief that the planned intervention or program is likely to result in the desired outcomes. The theory of change should be based on a review of the research literature and accepted learning and instructional theories. The ability to create a logic model and explain the associated theory of change are important skills for educational technologists, or at least those in leadership positions. The importance of this ability is why communication skills were stressed in the previous discussion.

Studies focused on the implementation are sometimes called fidelity of implementation studies and represent an important kind of formative evaluation. Studies focused on the outcomes are often called impact studies and represent a kind of summative evaluation. Impact studies are quite often primarily quantitative studies, whereas fidelity of implementation studies are quite often mixed method studies.

The logic model framework provides an important focus for research as well as for evaluation. It also provides a framework for design through the associated theory of change, which should explain at a high level why a particular approach along with specific technologies and support mechanisms are involved in the effort.

Logic models can provide a framework for research in a way that can help advance research in educational technology. By specifying the problem, goals, and objectives, and then details of the implementation and a justification of the approach, the basis of a number of research studies can then be designed and organized around those details. When the purpose, approach, methodology, and instruments are specified, the study can then be replicated in other situations (Makel and Plucker 2014; Spector et al. 2015). When replications studies and subsequent meta-analyses are conducted, the practice of educational technology can move forward on a scientific basis. While some do not appreciate the need for a scientific basis for educational technology, without such a basis we are left with the fads and fancies emerging from the technology marketplace and likely to repeat the mistakes of the past. The most obvious mistake is overpromising what will result from the adoption of a particular technology.

3.6 Concluding Remarks

The argument presented in this chapter is that there should be more emphasis on (a) research and evaluation, (b) training educational technologists in program evaluation and teamwork, (c) developing educational technology programs that are interdisciplinary and emphasize a wider range of knowledge and skills, and (d) what is needed to systematically improve learning and instruction for a sustained period of time on a large scale. In the past, educational technologists have promised too much and delivered too little, although some causes for falling short have to do with unreasonable constraints, inadequate support for training, and overlooking the need for ongoing professional development.

We can do better. The tremendous potential of new and emerging educational technologies demands that we do better. However, in order to make systematic and sustained progress in the effective integration of technology to improve learning and instruction, academic programs for teachers and technologies will need to be changed. In addition, more support for implementation will be needed, including support for training, maintenance, and professional development. Educational technologists will need to become more knowledgeable about program evaluation and educational research, including the ability to communicate research and evidence-based practice to decision makers.

In summary, the success of instructional design on a global scale depends less on advocacy and more on research and evaluation. In addition, success in the effective integration of technology in education will depend on the flexibility of instructional designers because technologies are likely to continue to emerge at an alarming rate that exceeds the typical imagination of this author.

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Chapter 4
Design for Linking Science Learning to the Informal Spaces

Chee-Kit Looi, Daner Sun and Wenting Xie

Abstract While learning in informal contexts has been discussed for decades, there has been limited attention paid to the influence of informal learning on students' learning in the formal spaces. Studies of students' thinking and doing in the informal context that relate to their learning in the formal context have not often been conducted. Toward the aim of bridging the gap between informal learning and formal learning, and studying the impact of informal learning on the formal learning with the use of mobile technology, this chapter introduces relevant definitions of informal learning, and then discusses the challenges encountered by the informal learning studies. Some design principles are articulated to suggest ways of integrating informal learning into the formal school system supported by the incorporation of technology use in science learning.

Keywords Informal learning · Science learning · Design issues · Mobile technologies

4.1 Introduction

Educators are debating the roles formal and informal learning play in the formal schooling system. Earlier research mentioned that the educational experiences for learners at home and other informal sectors, such as in science centers, are often in stark contrast to what is on offer in schools, and the ways learners interacted with

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their informal learning environments have changed obscurely (Braund and Reiss 2006). As a matter of fact, researchers have attempted to highlight the importance and the opportunities of informal learning provided for students by figuring out the proportion of time learners spent in and out-of-class. Braund and Reiss (2006) found that "pupils of school age spend about two-thirds of their waking lives outside formal schooling, yet educators tend to ignore, or at least play down, the crucial influences that experiences outside school have on pupils' knowledge and understandings, and on their beliefs, attitudes, and motivation to learn." Osborne and Dillon (2007) reflected that although the traditional viewpoint holds that the school is the sole site of learning, actually most children between 5 and 16-year old only spend 18 % of their waking hours in schools. Furthermore, OECD (The Organisation for Economic Co-operation and Development) reported that primary students receive an average of 802 h of intended instruction per year (with several OECD countries exceeding 900 h). This means that in the whole year comprising 8760 h, students only spend 9 % of that in their schools (OECD 2014). These statistics data reveals the limited amount of time students spend on formal learning. On the other hand, these figures also remind us that educational researchers should consider what students are doing and thinking in their informal contexts besides time spent in school. These informal learning experiences may have equivalent potential to promote students' learning.

The role transformation of informal learning has also been reflected in relevant educational policy documents. Organizations, consortiums, affinity groups, and publications concerned with science learning in informal environments have proliferated over the past 50 years (Lewenstein 1992; Schiele 1994). In science, the most popular ways for students to engage in their informal learning spaces are communicating and exploring science in museums, science centers, botanic gardens, zoos, field centers, etc. The importance of supplementing formal science education with museum visits is acknowledged by the U.S. National Research Council (NRC 1996, p. 3), which states that "The classroom is a limited environment. Museums have been conducting classes, delivering lectures, and designing special programmes for schools for over a century." However, it is only in recent decades that museums have received recognition for their value to formal education (Black 2005). The advocacy of extending the school science program beyond the walls of the classroom to the resources of the community particularly pointed to "learning in museums" as an integral part of science learning (Mortensen and Smart 2007).

Besides science learning, teacher education related to informal learning is also stressed. The revised version of Standards for Science Teacher Preparation (NSTA 2003) discussed the necessity of preparing teachers for relating the science discipline to local and regional communities and the natural resources of the community in their teaching. Teachers are encouraged to involve students in informal learning opportunities to conduct science-related activities such as field trips and issue surveys. Although the newly released Next Generation Science Standards (NGSS) does not emphasize informal learning, it calls for a deeper understanding and application of content to develop high levels of cognition in students through the practices of science. Consequently, exploring scientific phenomena in the informal learning settings can facilitate some of these needs (NGSS 2013). In Singapore, the Ministry of Education (MOE) recognizes the importance of balancing students' in-school and out-of-school activities so as to provide them with holistic development opportunities. They emphasize that apart from time spent in schools, students need to have time for revising school work, bonding with family and rest (MOE 2014). Thus, schools need to provide various opportunities for students to practice their knowledge and have learning experiences in their out-of-class time. In summary, the documents strongly endorse the use of informal science education institutions to support K-12 science instruction. However, the ways students interact with their informal learning space, and the outcomes of learning are still understudied areas with limited evidence for their educational efficacy.

Specifically, research on learning in informal settings such as museums has been in a formative state during the past decade, and much of that research has been descriptive and lacks a theory base (Anderson et al. 2003). The reasons we inferred are these: (1) Literature review has indicated that the depth of investigation of informal learning is much less than researchers' similar efforts on formal learning. (2) There is limited research that has looked into the connections between design and implementation of formal learning and informal learning.

Yet recently the need and possibility of integrating informal learning with formal learning has been increasingly acknowledged as researchers no longer hold a dichotomous view toward formal learning and informal learning, and they do recognize the educational value of informal learning. Educators and researchers are investigating the synergy of these two kinds of learning. Hofstein and Rosenfeld (1996) contended that "it would be useful if science educators would consciously utilize a wide range of out-of-school environments which foster science learning." They preferred to adopt the "hybrid" view (rather than the dichotomous) view that informal learning experiences can occur in formal learning environments (e.g., schools) as well as informal learning environments (e.g., museums, zoos). They recommended that future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science. Bell and others (2009) shared the same viewpoint that informal learning contexts should be seen as complementary to formal schooling rather than as in competition with it. Their report responds to the need for greater coherence and integration of informal environments and K-12 functions and classrooms, and the report urges a careful analysis of the goals and objectives of science learning in informal environments.

With the advance of the Information and Communication Technology (ICT), mobile devices (e.g., smartphones, tablets, PDA, and hand-held devices) have been absorbed into the fabric of our daily lives rapidly (Merchant 2012).The research of market trends on smartphones suggests that in the year of 2013 the volume growth of smartphones reached 15 % in Singapore (Euromonitor International 2013). The use of these devices has become pervasive and ubiquitous in many societies. Wireless, mobile, and ubiquitous technologies provide the learners with the opportunity to link a learner's experience across multiple locations (Luckin et al. 2005).

Relevant studies have demonstrated that the affordances of mobile technologies could support the learning taking place in informal contexts (Looi et al. 2014; Song et al. 2012; Sharples et al. 2014).

In science education, research on technological design, pedagogical design, and implementation and evaluation of smartphone-enabled learning (or mobile learning in a broad sense) has been accumulating, yet challenges remain in supporting teacher enactment and documenting evidence of student learning in mobile learning. Researchers have recognized the importance of getting insights into the mobile learning in the informal context, but challenges on the curriculum design and implementation, as well as the assessment of students' learning still exist. Jones and two others found that there is little literature that considers the structures needed to support informal and semi-informal inquiry learning (Jones et al. 2013). Mortensen and Smart (2007) points out that although there is a growing effort to create partnerships between schools and informal learning settings, documentation of such projects is limited, and is generally reported as examples of "best practices" with little discussion of challenges before or during implementation. A report of UNESCO (2013) points out that 270 million apps linked to education were downloaded in 2011—a more than tenfold increase since 2009, while a small number of educational apps are mapped to curriculum targets and designed for use in classroom or homework settings.

This chapter makes a case for designing for informal learning that can enhance formal learning. We will review the definitions of formal, informal and nonformal learning, and advocate a hybrid synergized view of integrating formal and informal learning. We will also review the role of ICT in the informal learning space, specifically mobile technologies. We will also present some design principles for enculturating informal learning arising from the findings of a seven-year longitudinal project on primary science education in Singapore, as well as highlight the challenges in understanding informal learning. Thus this chapter hopes to contribute to the discussion of the relevant issues from a design perspective of K-12 schools innovation concerning how to design and implement learning supported by mobile technologies for the informal context, and how to create the knots that connect the learning between formal and informal contexts.

4.2 Formal Learning & Informal Learning

In literature, three terms, namely formal learning, nonformal learning, and informal learning, are frequently discussed when researchers talk about the patterns of learning. From a design perspective, our research purpose is not to distinguish them or to endorse one of them, but to know when to utilize them and even merge them for students' learning. Below we first present two popular viewpoints on the relationship between formal and informal learning, and then we discuss ideas on how to make use of the merits of formal and informal learning.

4.2.1 Dichotomy Views on the Definition

People who hold a dichotomous view of formal and informal learning usually regard the two as isolated and separated learning patterns which take place in different places, time, with different learning objectives and educational value. Formal learning is the dominant learning pattern in the formal schooling system, in which informal learning is generally excluded. Below are the differences between formal and informal learning identified based on Hofstein and Rosenfeld (1996) and Braund and Reiss's work (Braund and Reiss 2006). Table 4.1 suggests that "context" is not the only criteria for differentiating formal and informal learning. Yet it is the corresponding curriculum, learning activities and pedagogy (e.g., pedagogical principles, teacher roles, and student roles), that distinguishes these two types of learning. However, distinguishing formal and informal learning has been blurred with the advocacy of dominant pedagogical principles, such as inquiry-based instruction, collaborative learning, and seamless learning (Chan et al. 2006). In the classroom, learner-centered activities are designed and conducted; group work is frequently conducted both in and out-of-the classroom; teachers take the roles of facilitators both in and out-of-the classroom.

Researchers and educators have devoted great efforts to articulate the differences between formal and informal learning. As Table 4.1 shows, from a traditional point

Table 4.1 Differences between formal learning and informal learning

Learning Patterns	Informal learning	Formal learning
Curriculum/learning activities	• Voluntary (voluntary; personal; individual) • Unstructured (free range, undirected, haphazard, unstructured, unsequenced) • Not assessed (not always assessment driven or extrinsically motivated) • Unevaluated • Noncurriculum based (not legislated for) • Many unintended outcomes • Less directed measurable outcomes (outcomes more difficult to measure)	• Compulsory (conformity and order is central; learning is compulsory and collective; timetabled, "forced" access; keeping people "together," "on track," on course) • Structured (directed, staged, sequenced, paced learning) • Assessed (assessment driven) • Evaluated • Curriculum based (legislated for; e.g., by National Curriculum or other statutes) Fewer unintended outcomes Empirically measured outcomes (measurable learning outcomes)
Pedagogy	• Open-ended (few boundaries and limits) • Learner-led (free access; learner control) • Learner-centered • Nondirected or Learner-directed (often unfiltered or unvetted) • Social intercourse	• Close-ended (clear boundaries and targets) • Teacher-led (teacher control) • Teacher-centered • Teacher-directed (teacher filtered, distilled, vetted) • Solitary work
Context	Out-of-school contexts (e.g., field trips, home)	School context (e.g., classroom)

of view, Wellington (1990) described informal learning as voluntary, nonassessed and learner-centered, with the social aspect being central, and formal learning as compulsory, assessed and teacher-centered, with the social aspect being less central. Crane et al. (1994) summarized that "informal learning refers to activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum, and are characterized by voluntary as opposed to mandatory participation as part of a credited school experience. Informal learning experiences may be structured to meet a stated set of objectives and may influence attitudes, convey information, and/or change behavior."

Beckett and Hager (2002) emphasized the potential value of informal learning context in triggering students' motivation. Compared to learning in the formal learning environment, students feel more comfortable and at ease in conducting the activities and interacting with their classmates in informal learning settings. Such pleasant learning experiences may create an intrinsically motivated student. Livingstone (2000) defined informal learning as all forms of intentional or tacit learning in which we engage either individually or collectively without direct reliance on a teacher or externally organized curriculum. This definition extended the traditional views of informal learning as beyond unintentional learning. In other definitions, the term nonformal learning is also used. Generally, formal learning is structured and takes place in institutions (e.g., schools or universities); informal learning is more unstructured, voluntary, and learner-led; nonformal learning is structured out-of-school learning with some features of formal and informal learning (Eshach 2007). In terms of educational value, it is believed that the informal science learning experiences can lead to further inquiry, enjoyment and a sense that science learning can be personally relevant and rewarding, while the formal learning is responsible for addressing the scientific knowledge needs of society (Bell et al. 2009).

4.2.2 "Hybrid" Views

Hybrid views refer to the viewpoints that formal learning and informal learning are not separated learning patterns. Informal learning can take place in the formal learning context, and vice versa. Learning will be enhanced or improved by the mutual interaction between students' learning in both of these two contexts. For instance, Dierking (1991) disagreed with the views of sharp distinctions between formal learning (taking place in schools) and informal learning (taking place in museums). He thought the physical setting is only one of a number of factors that impact the nature of learning. The learning taking place in the school and that in informal learning settings would probably be similar in type and quality if same focus had been paid.

Hofstein and Rosenfeld (1996) held the hybrid view that the informal learning experience can occur in formal learning environments (e.g., schools) as well as informal learning environments (e.g., museums and zoos). They view these two contexts as existing on a continuum, because a person's knowledge of science cannot be limited to what is learned in schools, as well as the types of learning opportunities. Scribner et al. (1999) pointed out that structured and planned apprenticeships were normally included in the informal category. A similar viewpoint was expressed in Billet (2001) that all learning tasks place within some social organizations or communities that have formalized structures. Thus, Colley et al. (2002) thought that it may not be the most profitable way to look for clear boundaries between formal and informal learning which can only be understood within particular contexts. It is difficult to make a clear distinction between formal and informal learning as there is often a crossover between the two (McGivney 1999).

Based on the above viewpoints, we found that both informal and formal learning has been developed beyond the traditional definitions. Their features have been merged in some specific contexts or guided by some specific pedagogical principles. Furthermore, in the context of seamless learning, formal learning and informal learning are treated as equally important when they are designed for promoting student learning. Seamless learning refers to the seamless integration of the learning experiences across various dimensions including formal and informal learning contexts, individual and social learning, and physical word and cyberspace (Wong and Looi 2011). In seamless learning, informal learning is usually structured as an extension of formal learning, and both informal and formal learning are assessed by indicators of students' progression.

4.3 Informal Learning for Science Education

In science education, learning outside of formal institutions is certain to be of growing importance in relation to the formal school curriculum (Wellington 1990). Morag and Tal (2012) contended that regardless of how they are defined, all out-of-school learning environments have a variety of cognitive, affective, social and behavioral effects that can make a significant contribution to learning. Outdoor experiences are a key part of both self-development and formal education. Many research efforts have been devoted to "bridging the gap between formal learning and informal learning." The call for integration is dominant. As Bevan et al. (2010) claimed that:

> … how communities, including school systems, can develop better and more integrated systems for, or habits of, understanding how science interest and learning that develops out-of-school is brought to and capitalized on during school.

Therefore, an increasing number of research projects on informal learning attempts to design the boundary activities or connected activities to bridge students' learning that occurred outside with their classroom learning. The informally acquired ideas or knowledge have been demonstrated to promote students' knowledge learnt in classrooms, and the mutual interaction of these 2 kinds of knowledge could make positive contributions to knowledge construction and elaboration.

Hence, it is important that the teacher connects students' experiences acquired in the field trips with concepts and lessons taught in the classroom. This would also refer to how to design informal learning for benefiting students' learning in formal learning contexts.

Studies also showed that the more students were exposed to informal learning contexts, the more benefits students would gain in relation to their formal learning. Gerber and others (2001) investigated and compared science learning in enriched informal learning environments and that in impoverished informal learning environments. The results suggested that students benefited more from their scientific reasoning abilities by interacting with various informal learning environments. This study also demonstrated the potential impact of informal activities on students' achievement in the formal classroom setting. From a more systematic viewpoint, Sanders (2007) investigated the relationships between students' botanical learning and their learning at school, home, and the botanic garden where three representations (i.e., living, model, and virtual) were provided. The positive results encouraged the teachers to be open-minded and to bring outdoor learning into the classroom. They would need to think about the dynamics of different learning spaces and different modalities of teaching. This might result in a shift in classroom life that could support a retreat from the current dominant culture of "monologues and tests" present in many classrooms.

In Behrendt and Franklin (2014)'s research, they emphasized the necessity of involving the pedagogies or principles of informal learning in teacher education. In their opinion, an informal education venue can be a valuable resource that reinforces classroom pedagogy. They recognized the importance for developing teachers' competencies on designing informal learning activities. As the school trip is an educational opportunity, it is important for it to fit into the curriculum. They emphasized the importance of content preparation prior to the trip, as well as follow-up activities to clarify remaining questions or reinforce concepts from the trip (DeWitt and Osborne 2007). They also suggested that teacher education programs should include experiential education and field trip preparation and implementation for all preservice teachers so as to help them understand the necessity of preplanning, participation, and student reflection. In current teacher training programs, this area has been somewhat neglected.

Theoretically, DeWitt and Osborne (2007) proposed a Framework for Museum Practice (FMP) to guide the teachers to design the resources for supporting students' museum visits. The evidence showed that FMP which connects informal learning activities with formal learning could promote student learning. The FMP consists of the following elements:

- Adopting the perspective of the teacher: it includes a serious consideration of the teacher's time (particularly classroom time) and the demands of any local or national curriculum standards.
- Providing structure: the structure or focus of the activities in the visits is provided, and students were encouraged to make connections between the visit and what happens before and after it in the classroom.

- Encouraging joint productive activity: it involves pupils working with each other and with the teacher toward an end product.
- Supporting dialog, literacy, and/or research skills: it considers skills beyond those most directly related to science topics.

In Gilbert and Priest's (1997) study, they mobilized external factors for promoting the effectiveness of students' museum visits and attempted to link their informal learning experiences with the topics learned via formal learning. They organized group activities for students to discuss the "critical incidents" in the visits, and meanwhile pre, during, and post-activities were designed for students to elaborate their knowledge in and out-of-the classroom. These strategies helped researchers to understand more about students' thinking and learning in the museum visits.

Kisiel (2014) proposed that combining resources from both formal and informal learning settings is an effective strategy that enhances student interest in science and STEM learning. He used a term "boundary activity" to define the activities which connected schools and informal science institutions. The term enables researchers to think about what these boundary activity look like? What are the best boundary activities? How to balance the different needs of the communities in these boundary activities? The creation of a joint practice-based enterprise is highlighted. The activities for both formal and informal settings should share similar objectives and desired outcomes.

Confessing the necessity of partnering the school and out-of-school learning environments, Phillips et al. (2007) pointed out that recent teacher professional development programmes tend to blend the elements of the less structured setting of ISIs (informal science institutions) with the more structured requirements and goals of the K-12 educational system. Using surveys, they identified the ways that the learning context, resources, and approaches of ISIs as well as the TPD programmes offered are contributing to school-based K-12 education. But they also pointed out the need to determine how ISIs can best support students and teachers in terms of actual curriculum and materials used within the classroom. They also found that ISIs better served more experienced teachers than novice teachers.

When teachers do focused pre-visit preparation of the informal institution, there is an improvement in student learning and attitude (Gilbert and Priest 1997; Patrick et al. 2013). Patrick et al. (2013) thought that field trips need to incorporate problem-solving skills, to be integrated into the curriculum, to focus on the standards, and to take into consideration the children's needs. Rickinson et al. (2004) demonstrated that if field trip activities are 'properly conceived, adequately planned, well taught, and effectively followed up', they can offer 'learners opportunities to develop their knowledge and skills in ways that add value to their everyday experiences in the classroom.' Sharples et al. (2014) proposed employing scripted learning methods to conduct outside inquiry activities. The teacher initiates a structured activity with the mobile devices inside the classroom, and then each student continues the investigation outdoors or at home, with the technology providing the function of orchestration. Results are then shared, discussed, and presented back in class. The research conducted by Falk and Balling (1982) indicates that without orientation and preparation, students are more likely to concentrate on nonrelevant aspects of the surroundings, rather than those relevant to the learning intended. Thus, designing structured outside learning activities and conducting scripted activities constitutes one approach for design of informal learning.

The literature cited and discussed above have demonstrated informal learning can be an integral part of the formal education if the learning objectives, content and design of the informal learning activities are well planned and designed undergirded by the relevant theoretical frameworks.

4.4 Mobile Learning in the Informal Space

With mobile technology, the science learning environment can be mobile and go with the students to the field site, to the laboratory and beyond (Martin and Ertzberger 2013). The extension of the learning environment enables students to investigate more science phenomena in real life and to demonstrate principles and scientific knowledge in different contexts other than the laboratory (Shih et al. 2010). Furthermore, social networking opens up opportunities for students to do socially mediated knowledge building associated with learning science by doing science at anytime and anywhere. Science projects with the use of mobile technology have demonstrated the merits of mobile learning and its learning effectiveness for students (Pea and Maldonado 2006). Sharples et al. (2009) mentioned that mobile learning offers new ways to extend education outside the classroom, into the conversations and interactions of everyday life. The use of mobile devices blurs the distinction between formal and nonformal learning. According to Hwang and Chang (2011), although there are multiple definitions of mobile learning, each focusing on a different aspect, they share the same idea, that is, the mobile device plays an important role in the learning activities no matter whether the activities are conducted in the field or in the classroom.

Compared to formal learning, informal learning happens across multiple contexts and timelines, which leads to challenges for the teachers to capture students' learning behavior outside the classroom and beyond the class time (Sharples et al. 2007). Although worksheets, students' self-reports, or on-site observations of the field trip may supplement the lack of evidence from informal learning spaces, the evidence on students' thinking, reasoning, and conceptual changes are harder to capture. One notion of everyday mobile practice was proposed by Merchant (2012) that the schools should not be irrelevant to the lives of the young people. Attention should be paid to the everyday mobile practices of their "sayings," "doings," and "relating." Advances in the ICT technologies, particularly the mobile devices, make the real-time monitoring and evaluation of students' learning artifacts and learning process in the informal spaces a reality. Importantly, the social interaction tools incorporated in the mobile devices could support the teachers to understand more about how students think and reason in the informal learning spaces, and how they interact with their partners (Otero et al. 2011; Terras and Ramsay 2012). In informal learning contexts, the use of mobile technologies together with appropriate pedagogies has been popular in facilitating students' learning.

Rogers and Price (2008) conducted two studies on exploring students' collaborative inquiry process incorporating different mobile tools in the field trips. Focusing more on students' interaction and their use of the various types of mobile device and tools, the study showed how the mobile device facilitated students' discussion, interpretation, sharing of, and reflection upon their inquiry. Another notable finding was the need of teacher cues, prompts, and feedback for supporting students' inquiry. The teachers acted more as facilitators than tutors or guides in the outdoor activities.

Vavoula et al. (2009) designed an inquiry-based learning platform called Myartspace for students to gather information in the school trips. The instructional design was accompanied by pre-and post-lesson of the museum visits. The post-lesson activities were supported by a website which stored shared and presented students' work done by Myartspace. The pre-and post-lessons in the classroom and the museum trip out of the classroom were bridged by the use of mobile device and the website. The outdoor learning activities supported by mobile technology facilitated students' conception construction and reflection in the classroom.

In another study, a mobile plant learning system (MPLS) installed in PADs was used for supporting students' outdoor investigation of plants through the activities of searching, creating, and sharing the knowledge of plants. The study revealed that the MPLS helped students to acquire knowledge and stimulate their motivation and enthusiasm in outdoor mobile learning, as well as in social interaction and discussion about the course materials (Huang et al. 2010). In Ruchter et al. (2010) study on the investigation of mobile computers in environmental education, the mobile tour system boosted student's learning about environmental literacy as well as their learning attitudes and motivation.

Song et al. (2012) proposed a goal-based approach to design a mobilized curriculum to guide students' personalized inquiry learning in primary science. The approach has indicated effectiveness in terms of developing scientific knowledge and self-directed learning skills in students. Ahmed and Parsons' (2013) study used a mobile learning system called ThinknLearn for supporting students' abductive science inquiry throughout the process of exploration, examination, selection, and explanation. The findings suggested that with mobile learning, students improved in their skills on generating hypotheses and critical thinking. Case studies conducted by Jones et al. (2013) explored the differences in students' inquiry in the informal learning and in the semiformal learning context. Their study especially focused on examining the learner control of inquiry and the way mobile devices (i.e., nQuire, Geocoaching) supported their inquiry. The findings revealed that if students were offered more control of the inquiry, such as the inquiry topics and methods, the inquiry would be more personally meaningful in the informal learning contexts.

In the seamless learning work of (Wong and Looi 2011), mobile technologies serve as a hub for the learners to integrate their learning activities in the formal, nonformal, and informal realms. In formal instruction, the teacher designs learning activities and uploads them onto a server, from which learners can download the learning activities to their devices. During the course of the activities, learners uploaded their artifacts or work-in-progress to a website for the teacher to review. The activities, which can be done anywhere anytime, were centered on the use of the device which allows them to search the Internet, download resources, collect or create digital artifacts, record their observations, communicate with their friends, and view the lessons and work on their assignments.

These studies collectively point out the particular role that mobile learning can play in informal learning in science education, and that the special educational value of combining mobile learning system/apps and the appropriate pedagogical approaches (e.g., inquiry-based principles) for students' science learning related to knowledge, skills, competences, and attitudes.

4.5 Design Principles for Enculturating Informal Learning

We have fore grounded the hybrid view of formal and informal learning for science education in a seven-year longitudinal research project on developing innovative curricula for primary school science in Singapore. For more information on the findings of this research, please refer to (Looi et al. 2014, 2015). In this section, we describe strategies from our design research on fostering seamlessness between formal and informal learning mediated by mobile technology. The research was conducted across various grade levels and subjects (science, mathematics, and Chinese language), over longitudinal time scales of seven years for science in a primary school in Singapore. The intervention comprised transforming the science curriculum to harness the affordances of 1:1 mobile technology for inquiry learning (Zhang et al. 2010). In the spirit of seamless learning, the researchers worked with the teachers, the students, and the students' parents to foster the continuous, pervasive, and longitudinal use of mobile technologies for learning anytime and anywhere beyond the confines of classroom.

We identified the following approaches to foster extending learning to the informal spaces and realms.

4.5.1 Extension of Learning Activities to Beyond the Classroom

An important design principle is to design for linking students' inquiry across formal learning and informal learning contexts. Teachers design student-centered mobile learning activities for informal contexts (e.g., home, science center, zoo, botany garden, etc.), and then seek to link students' conceptual understanding in the classroom formal learning environment with real-life experiences in informal learning contexts. For example, in a designed zoo trip for Primary 3 students, the science teachers designed the appropriate scaffolds and question prompts in the mobile app for the students to complete the tasks on the classification of animals according to their characteristics. With mobile tools, students took pictures and annotated the pictures of the animals and their habitats with short notes of their observations. These were then uploaded to a server. The students' uploaded artifacts were used by the teacher in subsequent discussions in their post-trip lessons. As a follow-up, teachers reviewed the students' observations, helping them to make connections of their observations to the concepts they learnt about the characteristics of animals in the class.

Thus, learning activities can be designed where the students engage in learning beyond the boundaries of the classroom. In primary science learning of plant systems, students are encouraged to be more observant of their surrounding during the course of everyday activities and learning outside the classroom. In the field trip, students took pictures of what the different plants they observed and uploaded them to a class blog. At home, the students conducted experiments (e.g., observing the growth of the bean sprout) and recorded the experiments on video and wrote their reflections with mobile devices. The general design principle here is to enculturate students to generate digital artifacts upon which there is a basis for personal reflections as well as for social discussions, some of which can happen in the classroom.

4.5.2 Design for Holistic and Authentic Learning

Science lessons can be re-designed to magnify the authenticity of the learning activities. In an activity for the science topic of life cycles of living things, students visited a butterfly farm where they were able to observe the different stages of a butterfly from the egg to an adult stage. Students were able to buy a butterfly caterpillar kit for home to observe the stages of the butterfly metamorphosis. The students took pictures of the metamorphosis from the caterpillar to the adult stages. Teachers were able to discuss with the students their observations and linked their experiences to the concepts they learnt about the lifecycle of animals.

A field trip to a probiotic drink factory was designed for Primary 3–5 students to learn about the presence of good bacteria in a drink commonly known to them and how the bacteria travel through their digestive system. In the trip, a learning connection was made between the concepts of bacteria being a living micro-organism and how the organs in the digestive system function in a human body system. They might also relate this to their experiences of stomach disorders when they eat contaminated food.

4.5.3 Design Student-Centered Learning Activities for Self-directed Learning

In all the science lessons, students were encouraged to use a KWL, a reflection tool on the mobile devices for their self-directed learning. The students shared their prior knowledge and generated questions concerning what they would want to know about the topic. They were encouraged to leverage on the device anytime anywhere to embark on their own research as well as to find the answers to any questions they might have. They used a search engine to find the answers, view videos or take pictures to answer their questions. Subsequently, they reviewed their own learning and synthesized what they have learned.

4.5.4 Make Students' Thinking Process Visible for Introspection and Discussion

Knowledge construction tools such as animation and concept mapping software were made available on the mobile devices to help students visualize their thinking process. For example, the students drew an animation of the plant transport system showing how water flows through the plant from the roots to the leaves and how food is transported from the leaves to the roots. The visualization tools are useful for teachers as they provide a window on the conceptual understanding of the students. They are also a good platform for learning as the whole class can be engaged in meaningful science discussion on what they see.

4.5.5 Facilitate Social Knowledge Building and Collaborative Learning

Rather than relying on teacher and textbooks as sources of knowledge, students conducted their own research and shared and discussed what they have learnt with other classmates. Students are encouraged to share interesting videos or pictures they have found to the class. Students brought in sources of knowledge they had found from the Internet and other resources into the classroom, and then discussed with their group members to consolidate their understanding. In addition, students shared knowledge on the use of the smartphone. They learned amidst the process of using the tool, and they shared what they have learnt with others in the classroom.

4.5.6 Assess Formatively from Peers or From the Teacher

Students were provided opportunities to receive feedback from their peers or teacher. In some activities, students exchanged their smartphones and gave feedback on their partner's work. Teacher reviewed the students' work formatively and assessed the student's understanding when they upload their work to an online learning management website.

School tests and students' worksheets were not the only assessment instrument tools. Students' performance in activities and the digital artifacts created by students are also indicators for teachers to evaluate the students' performance. For example, in the topic of "Exploring Materials" in the primary 4 science curriculums, students were required to complete a series of tasks. These included the construction of a concept map for materials classification after they had explored the different materials and their properties, and written their reflections in KWL. The students displayed their understanding by posting a picture of the product and listing its materials and properties. Students created these artifacts outside of the classroom, and then reviewed and commented by the teacher either in online mode or in the classroom.

4.5.7 Facilitate Participatory Learning Involving the Family

Family plays an important role in home learning. Activities were designed in which parents were involved in participatory learning activities with the students at home. In the lesson on the body's digestive system, the students were asked to involve their parents when back at home. They were tasked to ask the parents what they knew about the digestive system and to identify gaps in their parents' knowledge. They had to teach the parents what they thought the parents did not know and to interview their parents again to check their understanding. All the parent-child interactions were video- or voice-recorded with the smartphone. Back in the classroom, each student shared the recording with a peer by swapping their smartphone, and together they discussed and reflected on their own understanding of the digestive system. In turn, misconceptions were surfaced and challenged.

4.6 Challenges and Issues in Designing for Informal Learning

The above sections have articulated the rationale for harnessing the power of informal learning in science education and elucidated some principles for doing so in the context of primary science education. In this section, we highlight the current gaps in the scientific understanding of informal learning.

The most frequently discussed issues are the missing aspects of how students think, discuss, and reason when they interact with the informal learning environments. Researchers pointed out the following major causes for this issue, and most of them are related to the design and enactment of the informal learning activities:

A. Learning in the informal contexts is commonly designed as sporadic and ephemeral visits, which usually are positioned as supplementary to informal learning. Consequently, there are challenges in developing a deeper understanding of the science content and practices (Yoon et al. 2013).

B. When conducting such informal science learning visits, teachers do not establish clear and specific objectives for students' learning. This often results in little monitoring of the learning and limited questions asked for relating students' informal learning to the instruction in the classroom. Thus, although school trips to informal science institutions can produce conceptual affective gains, the processes by which they do so are not yet clearly understood (DeWitt and Hohenstein 2010).

C. The lack of follow-up of visits to informal learning environments leads to the missed opportunities to support newly learned scientific concepts, and sometimes reinforces unexpected and potentially inhibiting alternative conceptions in many students (Anderson at al. 2000). There is limited relationship, connection or commutation between learning in schools and informal environments (Griffin 1997). Further, research on school learning rarely builds on findings from informal learning research and vice versa. Thus, we know little about how these experiences can best be integrated into the school curriculum.

D. The lack of teacher competency and the specification of teacher roles in the informal learning context compromise the learning outcomes. Traditional teacher education may not emphasize the instruction of preservice teachers on planning, coordinating and orchestrating a field trip. Particularly, these activities also require organization, planning, and student reflection to maximize the learning experiences (DeWitt and Hohenstein 2010).

Another issue identified in informal learning research concerns the assessment of learning occurring in informal environments. The final report of the NRC (2009) on learning science in informal environments discussed that the conventional academic achievement measurements (i.e., standardized tests of science achievement) are too narrow and not well aligned to the outcomes of informal learning. The test instruments can hardly capture students' thinking and reasoning in the process of learning in the informal contexts. Methodologically, Otero et al. (2011) thought that compared to the formal learning research, the study of learning in informal contexts is not well established, which leads to the difficulty for capturing data and evidence that can inform learning in the informal context.

While there are research on using mobile technologies and integrating them into the informal learning activities, their focus has been on creating learning environments for leveraging the affordances of mobile technologies using activities with a short duration of at most a few weeks' time or add-on activities for supplementing some existing curriculum. There is no research that takes a holistic approach to defining and realizing sustainable learning with mobile technologies via immersing it into the national standard science curriculum for sustainable and scalable implementation and improvements. Also, little effort has been made to trace the trajectory of the transformation of teacher and student behaviors achieved through long-term innovation. Little evidence has been collected to inform the relevant studies on mobile technology use in the science classroom at scale. More fine-grained analysis is needed to better understand the processes by which mobile technology merges into the learner's daily life, and to look into the ways of that technology is used and integrated in students' daily life (Rogers and Price 2008).

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Chapter 5
Comparative Study on the Status and Strategies of Infrastructure Construction of ICT in Education Between China and the United States

Di Wu, Xiaorong Yu, Jingyang Rao and Liqin Yu

Abstract Starting with the high position of infrastructure construction of ICT in education and its real demands in China, this paper introduces its construction status in China and the United States from such aspects as broadband access, classroom environment and popularity of terminal equipment. Experience and enlightenment for infrastructure construction of ICT in education is summarized based on typical measures and strategies of broadband improvement, cooperation between governments and enterprises as well as national education network setting up in the two countries.

Keywords ICT in education · Infrastructure construction · Comparison

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5.1 Introduction

5.1.1 ICT in Education Is the Breakthrough Point and Important Support for the Realization of Education Modernization

As traditional pillar industries and resource-intensive industries are facing greater pressure of transformation, the third technological reform mainly indicated by new technologies has been the focus of attention in different countries. Progress in information technology exerts profound impact on every field in modern society including traditional education. The formation of a new education ecological system becomes a general trend. And countries have been attaching paramount importance to promoting innovation of education system through ICT in education and cultivating quality talented people that suit the needs of our times. Mainly, developed countries consider ICT in education a key strategy for enhancing citizens' quality, innovation, and national competitiveness. For instance, American government updates its National Education Technology Plan about every 5 years, clearly stating that significant structural reforms supported by technologies will be implemented in its education system. In the United Kingdom, JISC put forward ICT in education strategy and determined its development area in the UK. Singapore has issued a development plan for ICT in education every 5 years since 1996, providing strategic instruction for ICT in education.

ICT in Education holds a high position in China's development strategies. In the 18th CPC National Congress Report, it is clearly stated that we should regard the significant improvement of ICT as one of the goals of building a moderately prosperous society in all aspects, which fully reflects that the communist party and the Chinese government attach great importance to ICT construction. General Secretary Xi Jinping emphasized at the central government network security and information technology leading group that there will be no modernization without ICT, which indicated the paramount significance of ICT in education for education modernization. ICT in education as the breakthrough point and an important support for realizing education modernization is a strategic choice to improve educational quality, promote educational equality, and realize educational reform.

5.1.2 ICT Infrastructure Construction Is the Prerequisite of Realizing ICT in Education

ICT infrastructure construction was officially put forward in 1993 when the Clinton administration stated in the "information superhighway" plan that we should vigorously carry out the construction of education information technological facility by making use of opportunities in the information era. China emphasizes particularly the construction of ICT infrastructure in the process of advancing ICT in education.

It is stated in *Outline of China's National Plan for Medium and Long-term Education Reform and Development (2010–2020)* (Ministry of Education, China 2013) that infrastructure construction is the most paramount and the material foundation of and prerequisite for realizing ICT in education strategy. ICT infrastructure construction is therefore the first and most important step and keynote construction project of implementing ICT in education. It makes the development of ICT in education possible.

Fundamental to ICT in education, ICT infrastructure construction is the prerequisite to its realization. Although the content of ICT infrastructure construction varies in different phases in countries, views of its main technical indicators are generally consistent. In this paper, broadband access, classroom environment, and popularity of terminal equipments in China and the U.S. are mainly introduced.

5.2 Policies on Ict Infrastructure Construction in China and the United States

The United States has attached great importance to the role that information technologies play in promoting educational reform. To propel the development of ICT in education, the U.S. has formulated and issued a series of policy reports, legal policies and projects, as is shown in Table 5.1.

Compared with the U.S., China started ICT in education relatively late. It was clearly stated in The Third Plenary Session of the 18th CPC Central Committee that a significant task was to construct an effective mechanism of expanding the coverage of quality educational resources by making use of ICT means so as to gradually close the gap between districts, cities, and rural areas as well as schools. *National Development Plan for ICT in Education (2011–2020)* clarifies that one of the goals of ICT in education development in our country is to generally realize the overall coverage of broadband network (Ministry of Education 2012). In 2014, the *Implementation Plan for Constructing an Effective Mechanism of Expanding the Coverage of Quality Educational Resources by Informationization* mentioned that we should accelerate connecting schools through broadband network, which is the specific requirement of ICT infrastructure construction and important content of the "Connect-SCS" in the twelfth five-year plan regarding ICT in education. Connecting schools through broadband network includes two essential parts, one of which is to basically satisfy the broadband access conditions of various schools, the other to complete the construction of basic teaching environment under the network conditions. In terms of construction, it includes two tasks, one being providing broadband access condition for schools, the other building basic teaching environment under the network conditions in schools. The latter includes building network accessible multi-media classrooms for schools, providing teachers with a set of basic software tool and teaching resources and equipping a certain percentage of teachers with computers and enabling them to prepare a course and teach with network teaching resources after training (Table 5.2).

Table 5.1 Relevant policies and projects regarding ICT infrastructure construction in the U.S

Year	Policies and projects	Relevant content
1993	Strategy for National Information Infrastructure	Planned to invest $400 billion in building information network set up by computer database in 20 years
1996	Getting America's Students Ready for the twenty-first Century: Meeting the Technology Literacy Challenge (U.S. Department of Education 1996)	The first national education technological plan issued in the U.S., putting forward forward-looking demands on such specific hardware devices as multi-media environment and classroom network access
2000	E-Learning: Putting a World -Class Education at the Fingertips of All Children	Emphasized the wide application of information technologies from the perspective of e-learning
2004	Toward a new golden age in American education: How the Internet, the law and today's students are revolutionizing expectation (U.S. Department of Education 2000)	Put forward 7 action plans: enhancing leadership, taking into account reform budget, improving training of teachers, supporting e-learning and virtual school, encouraging use of broadband, moving toward digital content, building comprehensive information system to face the rapid reform of information technologies
2010	Transforming American Education: Learning Powered by Technology, National Educational Technology Plan 2010 (U.S. Department of Education 2010)	Established comprehensive infrastructure to enable all students and education practitioners to use it at any place and any time; proposed to build comprehensive infrastructure to serve for study from five areas including study, assessment, teaching, infrastructure and productivity

5.3 Status of ICT Infrastructure Construction in China and the United States

5.3.1 Comparison of Broadband Access

According to the data released by National Center for Education Statistics, 100 % of the public schools in America had access to broadband in 2003, an increase from 35 to 100 % in a decade. As is shown in Chart 5.1, construction of broadband access in China began later than that in America. By the end of 2014, among 333000 compulsory education schools, 239000 have already had access to broadband, a rise of less than 25 % in 2011 to 74 %. Schools with 10 M broadband access accounts for 34.6 %. As is shown in Table 5.3, the percentage of compulsory education schools with access to Internet in urban areas has reached 100 %, while that in rural areas is 67.4 %.

Table 5.2 Relevant policies and projects regarding ICT infrastructure construction in China

Year	Policies and projects	Relevant content
1999	Decisions on Deepening Education Reform and Promoting Quality Education	Put forward that we should vigorously improve the modernization of education technological means and ICT in education
2006	The State Informatization Development Strategy (2006–2020)	Put forward in *Action of State Informationization Development Strategy* that we should implement "Citizens' ICT Skills Training Plan", "Network Media Information Resources Development and Application Plan", "Minimizing Digital Gap Plan" etc., integrating ICT in education into National ICT Overall Development
	National Plan for Medium- and Long-Term Scientific and Technological Development Plan (2006–2020)	Made plan and layout for keynote fields and the priority, proposing to develop information technologies represented by smart sensing technology, Ad Hoc network technology and virtualized real-world technology
2010	National Medium- and Long-term Talent Development Plan (2010–2020)	The first plan for medium and long-term talent development in China, pointing out requirement of and direction for talent cultivation
	National Outline for Medium and Long-term Educational Reform and Development (2010–2020)	Emphasized that information technology has revolutionary influence on educational development so that we must attach great importance to it, clearly pointing out to speed up ICT process in education
2012	National Development Plan for ICT in Education (2011–2020)	Put forward to complete ICT in education goals stated in Outline for Education Plan, forming ICT in education system suitable for national education modernization development goal
	National ICT in Education Work Video Conference	Vice president Liu Yandong put forward that we should make effort to connect schools through broadband network, connect classes with quality digital learning resources, and connect students in cyber learning space (Connect-SCS) and construct public service platforms for educational resources and educational management.
2014	Implementation Plan for Constructing an Effective Mechanism of Expanding the Coverage of Quality Educational Resources by Informationization	Accelerated connecting of schools through broadband network and gradually constructed necessary infrastructure that meets the application demands of ICT in education and teaching

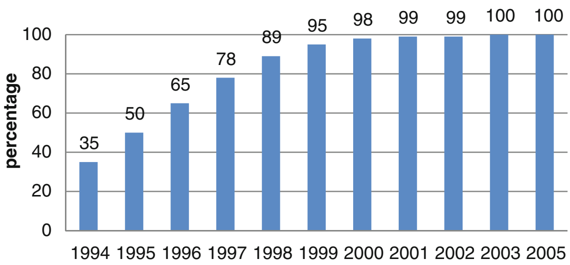

Chart 5.1 Broadband access condition in the U.S. Public Schools (Wells and Lewis 2006; Thomas and Lewis 2010a)

Table 5.3 Comparison of compulsory education schools with access to network and multi-media classrooms between urban and rural areas

	Average	Urban areas	Rural areas
Percentage of compulsory education schools with access to internet (%)	74	100	67.4
Percentage of compulsory education schools with multi-media classrooms (%)	73	95	69.4

5.3.2 *Comparison of Classroom Environment Construction*

The percentage of public schools with access to Internet in America keeps going up. According to National Center for Education Statistics, in 1993 only 3 % of the public schools had access to Internet, while in 2005 the percentage rose to 94 %, as is shown in Chart 5.2. In China, multi-media classrooms in middle and primary schools were mainly composed of projector, screen, controlled computer, and necessary audio equipment during 1990s and the beginning of this century. However, as now more and more emphasis has been put on interactivity, such equipments with good interactive function as interactive electrical white board, large-screen touch LCD machine has gradually been used in classroom. Meanwhile, ICT teaching terminal

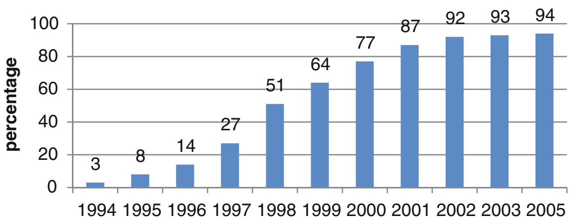

Chart 5.2 Rates of American Public Schools with Access to Internet in Classrooms 1994–2005 (Wells and Lewis 2006)

has gradually been updated. While traditional multi-classrooms composed of projector, screen, controlled computer are still widely used in middle and primary schools in our country. By 2014, there have been 2.25 million multi-media classrooms in compulsory education schools in China, accounting for 59 % of all classrooms. The rates of multi-media classroom in urban and rural schools are 81 and 49 %, respectively. 243,000 compulsory schools nationwide have multi-media classrooms, accounting for 73 % of the total number of compulsory schools. Among them, 34.2 % schools are totally equipped with multi-media classrooms. 95 % urban schools and 69.4 % rural schools have multi-media classrooms. Percentage of schools with access to internet in 10 provinces is up to 90 % and percentage of schools with multi-media classrooms in 8 provinces is up to 90 %. Therefore, network teaching environment in schools has been largely improved.

5.3.3 Terminal Device Popularity and Comparison of Its Popularity Condition

With the improvement of information technological means, the ages of student using terminal device have become lower. According to *Zero to Eight Children's Media Use in America 2013*, up to 63 % zero to eight years' old American children used smartphones in 2013 and up to 40 % of them used tablet devices. In the same year, *The Seventh Research of Chinese Minors Using Internet Condition* shows that rates of urban and rural minors using mobile terminal to surf the Internet were 61.2 and 60.6 %, respectively. Currently, ICT terminal for teachers and students in middle and primary schools mainly include PC, including desktop and laptop, tablet computers, smartphones, and other terminal devices. Among them, PCs are the ICT terminal devices that are used most widely and for the longest time. They have been used in most middle and primary schools for quite a long time. According to the report of National Center for Education Statistics, the ratio of American public school students to networked computers was 12.1:1 in 1998, which shrunk nearly four times to 3.1:1. The ratio of students to computers in China has a big gap with that in America. In 1999, the ratio was 128:1 and in 2013 it reduced to 11.64:1 (Educational Informationization Strategy Research Base 2013). Apart from the rapid change of ratio of students to computers, the rate of teachers using computer also changed rapidly. According to the official report of National Center for Education Statistics, 99 % American teachers had their own computers in 2009, nearly up to 100 % (Gray et al. 2010). While by the end of 2012, the average ratio of teachers to PCs in China was 1.86:1 (Educational Informationization Strategy Research Base 2013). Despite its big gap of ratio of students to computers with that in America, China has developed quite fast in this ratio and the gap has been narrowing (Chart 5.3).

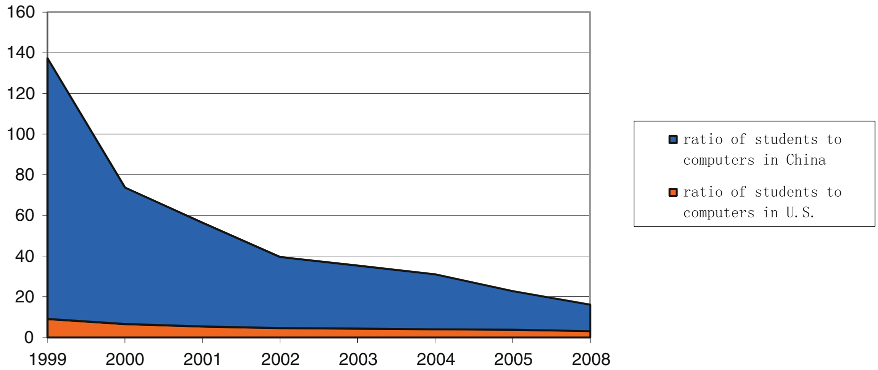

Chart 5.3 Comparison of ratios of students to computers between China and the United States (Wells and Lewis 2006; Educational Informationization Strategy Research Base 2013; Thomas and Lewis 2010b)

5.4 Strategies for Ict Infrastructure Construction in China and the United States

5.4.1 Strategy of Improving Broadband and Providing Education Compensation

In 1988, the United States started the E-rate program which provided discounted telecommunications, Internet access, and internal connections to eligible schools and public libraries, funded by the Universal Service Fund (USF). The discounts range from 20 to 90 %, with higher discounts for poorer areas, which has brought more interest to rural and poor schools and changed their poor ICT condition. The year 2013 witnessed another program called ConnectED which intended to popularize fast-speed Internet among all students from kindergarten to 12th grade in America in 5 years by equipping all classrooms with Internet interfaces and bandwidth of at least 100 Mbps (The White House 2015).

In China, the *National Development Plan for ICT in Education (2011–2020)* released in 2012 determined one of five general goals of ICT in education development in China as basically realizing the full coverage of broadband in every school. Specifically speaking, by the year 2015, every school will have access to broadband network, with over 100 Mbps bandwidth in middle and primary schools and over 2 Mbps bandwidth in remote rural areas. In 2012, the term "three connections and two platforms" was officially put forward at the National CIT in Education Work Video Conference. In this term, connecting schools through broadband network is the requirement of infrastructure construction of ICT in education in China. As for share of quality digital educational resources, by the end of 2014, 550 million RMB has been invested in successfully equipping about 70000 teaching places with facility, resource distribution, and teaching application in 2 years. Over 80 % remote rural teaching places have opened all prescriptive courses including music, fine art, and English. Generally speaking, compulsory education has improved significantly in balance development.

5.4.2 Mechanism of Cooperation with Enterprises to Enlarge Market-Oriented Operation

After the ConnectED program started, Apple Inc. promised to donate a worth of 100 million US dollar's ipads, apple computers, software and other devices; AT&T and SPRINT provided free Internet service through their wireless network; Verizon offered up to 100 million USD cash and non-cash donation; Microsoft offered discounted Windows and 12 million free Microsoft office software. AT&T and SPRINT would offer wireless broadband service to American students form low and medium income families for several years. Verizon and Microsoft would involve themselves in teacher training program; meanwhile, Microsoft and PC manufacturers combined to produce cheaper tablet computers and laptops for students. Autodesk will contribute a worth of 250 million USD 3D designing software and training programs (U.S. Department of Education 2014). By taking the multi-parties cooperation mode, Americans take full consideration of schools development objective and regional development background and set forward-looking infrastructure construction goals. And consideration of the development direction and route of infrastructure construction from various aspects and perspectives is conducive to scientific decision of planning infrastructure construction, optimizing resource distribution and enhancing supervision, and testing so as to speed up the process of ICT infrastructure construction.

It is emphasized in the *National Development Plan for ICT in Education (2011–2020)* that we should form virtuous competition industrial development environment, attract enterprise to involve in construction of ICT in Education, instruct the combination of industry, learning, research and application, promote enterprise technological innovation and form some highly competitive pillar enterprises which support the development of ICT in education. Meanwhile, we should encourage enterprises and social forces to invest and involve in construction and service of ICT in education, forming multi-channels to collect fees for it.

In terms of environment construction and mechanism innovation of ICT, the city of Jiaozuo in Hunan province has actively explored the network access mode of enterprise investing in construction and schools purchasing service. When constructing educational metropolitan area network (MAN), it has largely saved capital investment and ensured the sustainable development of MAN by introducing competitive mechanism. Through introducing market-competitive mechanism and reaching cooperative agreement with several enterprises, the Bureau of Education in Mianzhu has constructed fiber educational MAN and broadband accessible to all schools in the city at low cost. The Bureau of Education in Nanshan District, Shenzhen has guaranteed the educational funds, actively explored cooperation with enterprises and service outsourcing modes and achieved phase progress. These pilot units have gained favorable experience in the process of actively exploring innovative mechanism, sustainable development mode.

5.4.3 Educational Scientific Research Network in Support of High-Speed Network Service

The main purpose of Internet 2 backbone network is to provide reliable network service for high performance and advanced network application and powerful test platform for study of innovative network application technology. The backbone network connects over 60,000 scientific research institutions and interconnects with academic websites of over 50 countries (China education and research network 2012). Currently, China Education and Research Network (CERNET) and China Education Broadband Satellite net (CEBSat) have covered all across China and realized interconnection. At the same time, some provinces and cities have constructed provincial and municipal education websites based on fundamental service provided by network operators, providing high-speed network service for regional educational management and resource application. In terms of construction and application of educational resource platform, the National Public Service Platform for Digital Educational Resources built and operated by the National Center for Educational Technology, was visited over 1 billion times in 2014 and its users covered 100 million middle and primary school students of 150000 schools nationwide. And nearly half of all teachers have opened accounts in this platform. What is more, Provincial Public Service Platforms for Educational Resources have been built in nearly two thirds of provinces or autonomous regions in China, forming good complement to the national platform.

5.5 Experience and Enlightenment of China's Infrastructure Construction

Value top level design and encourage pilot program to promote the deep integration of education and technologies. The prerequisite position of infrastructure construction determines that the construction should not be carried out by blindly following certain rules and standards. China and America have taken steps to promote ICT policies efficiently based on their own practical conditions. Through top level design, we have drawn the blueprint for ICT in education undertaking in China. Thanks to the National Development Plan for ICT in Education, specialized conference on ICT in education nationwide and core policy document issued by several ministry committees, we have determined five key tasks of national ICT in education. Therefore, China's ICT in education undertaking has been carried out in good order without blindness. What is more, pilot programs provide valuable experience for promoting the deep integration of education and technologies by adjusting measures to local conditions.

Value the government's leading role and encourage multi-stakeholder participation to construct a benign circle of development ecology of CIT in education. Led by joint and cooperative projects, promoted by specialized organizations, Americans can centralize advantageous resources maximally and motivate CIT in education to ensure the smooth implementation of the project. The Chinese government has established specialized service institute across the country with the support of National Center for Educational Technology. In order to give full play of the advantages of market resource allocation and personalized product service, we have adopted the methods of government-dominated investment of non-profit facility and resources and enterprise investment of personalized facility and resources through competition. As a result, we have not only gathered forces from all walks of life but also helped produced new industries.

Value the building of educational and scientific research networks and set up nationwide cloud service platform. In construction and management mode, educational network mainly depends on government investment and enterprise sponsorship. As educational and scientific research networks in China mainly serve universities, we must set up nationwide service platform. With promoting the socialization of low-carbon education and collaborative education theory as its core, cloud computing can bring changes to environment construction, resource construction and teaching modes for education. Nationwide cloud service platform brings innovative opportunities for CIT in education in schools, meanwhile it is significant for constructing an innovative country. Cloud education platform makes information communication rapid, convenient, and cheap, which is conducive to increasing management efficiency and reducing management cost. Moreover, administrators can learn about teaching and management conditions of a school through this platform so as to find problems in time and put forward improvement solutions and measures accordingly.

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Part III
Development Model of Digital Learning Resources

Chapter 6
Developing Digital Learning Resources for Teachers' Needs: The Project from China

Liang Yu, Chuqian Sheng, Yimeng Yang and Di Wu

Abstract In order to bridge the digital divide between the western remote rural areas and the developed areas and improve the educational level of the teaching sites, MOE of PRC published the Teaching Site Covered by Digital Education Resources Project. This paper introduces the background, aims, and the project tasks that the government should equip the teaching sites with high quality digital education resources to meet teachers' needs. Besides, it sets forth the transmitting mode, organization method, and the application method of digital learning resources, which gives two application cases from remote rural areas of China as well. In the end, the effect, problem, and further development suggestions of the project are put forward.

Keywords Digital learning resources · Project · Teaching site

6.1 Introduction

China has the largest volume of information technology users and this digital structure continues to grow. In 2013, China had 1229 million mobile telephone subscriptions, 45.8 % of individuals using the Internet, and 188 million broadband subscribers, which compares to the respective totals in the United States with 305 million mobile telephone subscribers, 84.2 % of individuals using the Internet, and 91 million broadband subscribers (ITU 2014). China has moved to the first place among nations in its volume of ICT use, which is an advance that predominantly took place since the turn of the twenty-first century.

Diffusion of the Internet across China is suffering a severe challenge arising from the immense digital divide, where the mid-western regions are lagging behind the eastern and southern regions. The digital divide is getting so protuberant that it has

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been taken as the fourth gap in China, in the wake of the three gaps of urban–rural incomes, industry–agriculture, and brain–physical labor, which have had an adverse impact on the economic and income growth in the mid-western region (Recker et al. 2004; James 2008; Robinson and Wenwu 2009; Xie and Qi 2013; Mubarak 2014). A negative loop is formed among low productivity, low demands for modern technology, lack of high-quality human resources, low emphasis on improving human quality, and limited material resources (Yu et al. 2005). All of these hamper investment in education, although education is the most important way to bridge the digital divide. This lack of educational investment helps to perpetuate other deficiencies in turn.

China faces the major challenge of breaking this vicious circle and jump-starting the development of education, thus fundamentally reducing the gap in educational resources, beliefs, methods, and systems. Bridging these gaps will improve economic interaction among the local areas of these provinces, and will promote the use of IT and education for IT. To achieve this goal, since 2002, the Ministry of Education (MOE) of the People's Republic of China has invested about 10 billion Yuan in its Rural Area Modern Distance Education Project, which aims to improve K12 education in rural regions. In addition, this project has enhanced the basic infrastructure, teachers' teaching level, and instructional condition of K12 in the mid-western region of China in the next 10 years.

In order to solve the problem of deficiency of education resources in teaching sites located in remote rural areas of China, MOE launched the Teaching Site Covered by Digital Education Resources Project (TSCDERP) in 2012, which extended the Rural Area Modern Distance Education Project.

This paper will introduce TSCDERP and review its development. Furthermore, application cases are provided to demonstrate the practical situation of how the teachers use the digital learning resources of the project. The effect, problem, and further development suggestions are addressed based on the deep analysis of the project. As the typical digital learning resources project from China, TSCDERP can offer enlightenments for other countries' digital learning resources construction.

6.1.1 The Background of the Project Launched by the Chinese Government

The teaching site is generally located in remote mountainous areas that are not convenient, are on a small scale, and generally only have one teacher with 10 students around. In these teaching sites, the teacher needs to teach all the courses, and they also need to undertake logistics management services.

In addition, the teaching site generally has poor infrastructure, seriously lacking in high-quality teaching resources and modern multimedia teaching equipment, such as computers, and whose teachers mainly teach students in the most traditional teaching methods.

The teaching site is an important form of organization of school education, which facilitates low-grade students to study in the nearest school; there still remain a considerable number of such small schools and learning centers in remote rural areas of our country, whose number is about 67,000.

The teaching site is the weakest link in elementary education in China. They are mainly distributed in the deep mountains, border islands, and desert grasslands which have inconvenient transportation, poor geographical circumstance, and less-qualified teachers. However, the teaching site is indispensable to ensure rural school-aged children in the remote areas to go to the nearest school. In order to implement the guiding principles of the Eighteenth Party Congress and the national education informatization conference, the Ministry of Education of China enacted the embodiment of the project of ALL Teaching sites Cover with Digital Education Resources, which on the basis of the opinions of the general office of the state council on standardize, the rural compulsory education school layout adjustment and the notification of the Ministry of Education, and other nine departments on accelerating the present several important jobs of education informationization. MOE released a notification of starting the implementation of the project, ALL Teaching sites Cover with Digital Education Resources on November 19, 2012, which officially started the project. The Ministry of Education takes charge of the project, formulates the overall plan and schedule, provides guidance and supervision, and helps various regions to manage and push digital education resources. On the basis of the overall plan of MOE, the provinces or municipalities should formulate a local project implementation plan, organize the tendering, procurement and installation of equipment, provide digital education resources suitable for local teaching sites' actual demand, and organize the training of teachers' application ability. Meanwhile, the provinces or municipalities should also supervise and guide the teaching sites to carry out teaching with the equipment and digital education resources, and organize a technical force to manage and maintain the equipment.

6.1.2 The Aims and Tasks of the Project

The construction goal of the project of ALL Teaching Sites Covered with Digital Education Resources is to provide digital education resources receiving and playing device and high-quality digital education resources for the teaching sites that are necessary to be reserved and recovered in the rural compulsory education school (Chen 2014). The project aims at playing the role of a central school in the county, transferring high-quality digital education resources to 67,000 teaching sites throughout the country by IP satellite, organizing the teaching sites using these resources to develop education, using IT to help schools in the remote rural areas take courses prescribed by the state, upgrading educational quality, promoting balanced development of compulsory education, and helping rural school-aged children in remote areas take a good education at the nearest school. The project intends to achieve these goals within 2 years, which is, starting to arrange all the teaching sites of equipment procurement and configuration in 2012, and complete installation of all the eastern teaching sites and 70 % of the central and western teaching sites before March 2013. After the start of the spring of 2013, local education departments organized local teaching sites using equipment and resources to develop education. At the end of 2013, the project finished construction mission of all the teaching sites.

The construction contents of the project of ALL Teaching Sites Cover with Digital Education Resources include supporting each teaching site to build the basic hardware facilities that can receive digital education resources and carry out teaching using these resources, and transferring digital education resources to each teaching site by satellite. For areas where information construction is more advanced, the local government can base on the support of state revenue to further increase investment, such as increasing the configuration or using more advanced technology and application solutions, and raising the application level of equipment and resources. The funding gap can be complemented by local financial support. Besides, for schools that have network access should be equipped with cameras that can use the network to establish a parent–child hotline to meet the needs for conversation for left-behind children and their migrant parents (Chen and Weng 2014).

From November 2012 to the end of January 2014, in the 58,000 teaching sites that implemented the project of ALL Teaching Sites Cover with digital education resources, there were 57,800 teaching sites that completed equipment bidding which accounted for 99 %, 51,700 teaching sites completed equipment installation and debugging which accounted for 89 %, and realizing receiving and using digital education resources by satellite and network. The Ministry of Education established a special website of teaching sites and call center hotline, providing Online FAQ and consulting for teachers of the teaching sites and for carrying out remote tracking guidance and services. From September to December 2013, the average daily visitors to the website of teaching sites were 13,000 and the average daily resource downloads was 1.5 TB. Besides the teaching sites, there were many primary school downloaded resources from the website. Education departments around the country gave great impetus to the project and realized equipment, resource distribution, and teaching application in the teaching sites.

6.2 Digital Learning Resources Provided by the Project

6.2.1 The Transmitting Mode of Digital Learning Resources

As adjusting the layout of teaching sites is affected by the local economies and policies, the conditions of the teaching site in different regions exhibit an uneven phenomenon. Some teaching sites have a complete satellite data receiving device that can receive the distance education project in rural digital resources through the ground network, and some places have access to the network with computers and other devices, so they can use the Internet to get the teaching resources. There are also some teaching sites with no modern teaching equipment. Therefore, to ensure that the digital educational resources developed by NCET are able to reach all of the teaching sites, teaching sites of the project are set to receive Internet mode, satellite reception mode, and center school copy mode, so that all teaching sites can receive high-quality digital resources (Zhang 2014).

6.2.1.1 Internet Mode

In the teaching sites that have access to the network, they can log into the project site to download resources. The left column in curriculum resources is of optional discipline and grade. After selecting grades and subjects, you can choose to download unit teaching content according to your needs. In addition, the home-of-the-week curriculum column guides you to download the required curriculum resources. The curriculum also recommends teachers to download the learning resources for the week, and also provides a two-week course before and after each week to prevent network failure or other causes, such as download of resources unsuccessfully, so that they are available to view and download the lack of curriculum resources.

6.2.1.2 Satellite Data Reception Mode

To receive digital resources by satellite equipment, some equipment we need are a computer station, a receiving antenna set (including tuner), splitters 1, IP data reception card, and an LCD TV or projector or a desk whiteboard. Teaching sites with satellite equipment installed can be opportune to watch satellite digital TV broadcast air classroom programs, and digital resources can be downloaded to the local computer to prepare for contingencies. Downloaded satellite resources are stored in the local computer by default at D disk, but you can change the storage location of the download according to your habit. Download resource folders are generally named JXD on behalf of teaching sites.

6.2.1.3 Center School Copy Mode

For the teaching site with no network conditions and no satellite receiving equipment, the audiovisual education center museum will grant an 1T hard drive storage capacity for each teaching site. The central school can copy the digital teaching resources to the hard drive though network or satellite. With the help of center school, teaching sites can use digital resources in hard disk to teach students.

6.2.2 *The Organization Method of Digital Learning Resources*

Digital educational resource websites include project site dynamics, curriculum resources, training dynamics, subjects' answers, and special education, which are shown in Fig. 6.1. Important notice project reports the provincial and municipal news projects to promote information; there is a variety of relevant information at all levels. Curriculum resources aim at elementary grades one to three, providing teaching and learning resources for teachers and students, and covering Chinese, mathematics, English, social morality, science, music, art, sports, and other subjects. Training news gives timely reports on various topics of training activities for teachers, administrators, technicians, and other people at all levels to carry out all kinds of areas. Subjects' answers are provided by expert lectures on digital educational resources to guide teachers to effectively use resources. In addition, it is to explore and show excellent review lessons of teachers and experts ideas about these lessons. Special education revolves around life, recreation, safety, and other topics designs in teaching resources, so head teachers can use them as references for the class theme activities.

Fig. 6.1 Digital learning resources website for the project

6.2.3 The Way of Using Digital Learning Resources by Teachers and Students

There are two clues of presentation of digital content resources (see Fig. 6.2), one supports classroom teaching and provides a relatively complete teaching resource, whose corresponding section is "school teacher," the other gives materials for students to use digital resources to autonomously study, whose corresponding section is "self-learning."

Digital resources, according to classroom teaching progress, include "lead into new courses," "learn something new" and "summary" three steps to support teaching, in which "lead into new courses" mainly is in the form of resources associated with the content of text messages and pictures; "learn something new" contains video materials, text, and image resources; and "summary" is mainly used to present the focus of teaching.

In addition, in order to help teachers make better use of digital resources, the platform also provides a "expand resources" module. There are some differences between the contents of different subjects including active scripting, expand reading materials, instructional design, and other common problems. Overall, this module gives users a reference resource for each class on instructional design and common classroom problems. You can download examples of lesson plan documents, but other form of resources only support browsed online and cannot be downloaded. The FAQ section is mainly about carding important and difficult points, and analyzing students' common problems. The following is an example of grade three for the Chinese test (standard version) first lesson "Swallow"; the curriculum main interface is shown in Fig. 6.3.

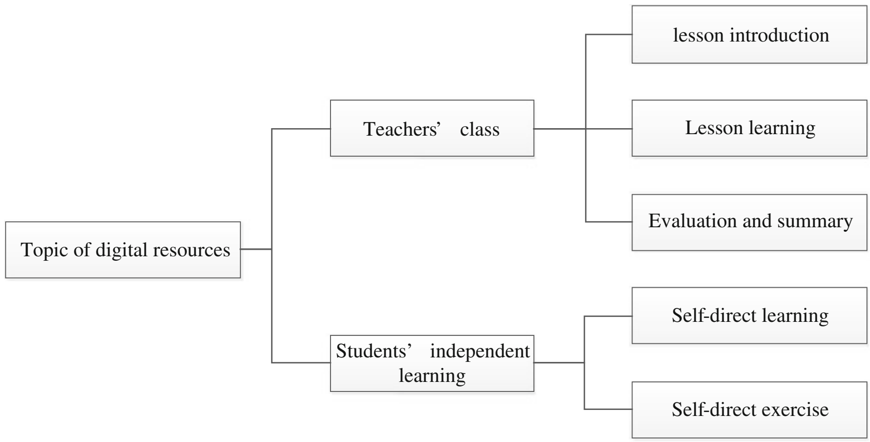

Fig. 6.2 The structure of digital resources

Fig. 6.3 "Swallow" the main interface

"Swallow" provides two cases of digital resources, shown in Table 6.1. From the perspective of supporting teachers in class, the first class consists of four parts: lead into new courses, read the text, word learning and summary; the second class contains review import, learning lessons, learnings and summary, four sections.

From the perspective of supporting students learning, the first class pays attention to explain vocabulary words, and the second class pays attention to the content of text. First class and second class resources give materials for two modules, namely the "follow me" and "students practice." "Follow me" is

Table 6.1 "Swallow" resource information sorting

	School teachers	Self-learning	Expand resources
First class	Lead into new courses, read the text, word learning, summary	Follow me, students practice	Activity design, sample lesson plans, FAQ
Second class	Rreview import, learning lessons, learnings, summary	Follow me, students practice	Activity design, sample lesson plans, extend reading, FAQ
Morphological	Text, images and audio	Text, pictures and video	Text-based, document supports download

composed of the text materials of self-learning and classroom instructional videos (embedded hyperlinks to look up learning objectives) constituted of video reproduction teaching situations to help students construct new knowledge. "Students practice" module is document-based, which allows users to find, zoom, full-screen to read, print, and download.

In addition, the expansion of the resource section of several parts includes several parts: the activities of design, sample lesson plans, the FAQ, and expand read. Activity of design and sample lesson plans use document rendering, which can be found, zoomed, full screen to be read, printed, and to be downloaded. The FAQ presents main and some potential problems of study in text. Then expand reading helps learners to better understand the content of the text, and to promote the transfer of learning through the picture material.

6.2.4 Application Cases from Remote Rural Areas of China

6.2.4.1 One Music Class by Teacher Zhou

The number of aging teachers in teaching sites is becoming larger, and some specialized courses such as audio, body, beauty cannot open enough courses in accordance with state regulations (Duan 2014). Especially in music appreciation class, teaching in the traditional way it is difficult to mobilize the enthusiasm of the students, and it is hard to do a good job of music teaching by music teachers with high-quality, while digital teaching resources solve this problem effectively (China Education Daily 2015). It has injected vitality into rural students for music classes, fostering their music perception and interest. Yixiao Zhou is a teacher of music appreciation, who has taught mathematics for 30 years and is poor in singing, while with this resource he gives a good example on the "Waltz jump kitten" teaching. First, he clicks to play music clips, students have to name the animal they had listened to. As soon as the cat in the song calls, students know the result of the animal friends in unison is "cat." Then the students are allowed to listen to the music, and ask: "what is the animal doing?" This leads to the song name—Anderson, an American composer orchestral song "Waltz jump kitten." Based on school teachers' teaching process, they make use of "segmented appreciation," "full appreciation," and "classroom summary" to complete teaching. Throughout the teaching process, Zhou hardly uses any knowledge of music, entirely in accordance with "school teacher" process organizing the class, and students complete appreciation of music in a relaxing and comfortable learning atmosphere; at the same time they show great interest with great teaching results.

Zhou said: "With this resource, the music lessons become easy and interesting. The lyrics and rhythm are sight-singing fan, it can be looped again and again, and students can sing along with the accompaniment and master the main point easily. It is very visual and easy to use. Students all feel the class becoming more interesting than before. They follow the teacher to learn what he said, now they can not only learn from a teacher, but also learn on computers, making learning vivid and convenient. The knowledge is waving hands to them. ”

6.2.4.2 The User Experiences from Teacher Zheng

To open enough and various courses, Zheng teaches Chinese, mathematics, character, and life subjects and is also responsible for teaching music, P.E., and art (Wang 2013). Without this equipment, there are very few students all day long with an old teacher teaching for a living. Simple lifestyle and simple teaching methods restrict the teaching quality, greatly limiting students' growth who live in villages.

Now the classroom is different! Zheng said, in the Chinese and math class, he creates different learning environments depending on the learning content. Using vivid picture and sound to replace the abstract text and using the form of animation to show the process of writing new words, not only makes up for the lack of knowledge of their own, but also emphasizes the focus of Chinese and mathematics learning and breaks the difficulties. The students' thinking and manipulative ability is greatly improved. Witty and vivid animation and beautiful music make the class a concert, and the students along with the music and video sing and dance, learn the songs easily, and side-by-side their hearts are nurtured. The PE class is more vibrant as well, where the video explains lessons step-by-step, and the students learn the lessons quickly and accurately. Art class used to be the biggest headache for Zheng, because he was not interested in art himself. He let go teaching outstandingly, and in art class students were free to play. But now the students are most interested in art class. Each teacher and student watches videos together, and then the teacher guides them to draw a picture directly on the whiteboard.

Zheng concluded, “With the digital resources of teaching site, teachers can stay at home to accept the influence of a number of advanced concepts, then these ideas become scientific instruction for our teaching and education, and often a subtle coaching may be able to solve years of doubts. I think the significance of the project is to promote the professional development of teachers. In the vast world of digital resources, we get lots of knowledge, but what the most important is the concept, a belief that takes technology into teaching, will always guide us to explore and make progress.”

6.3 The Effect, Problems, and Further Development Suggestions of the Project

6.3.1 The Effect of the Project

The advance of the project of ALL Teaching sites Cover with Digital Education Resources has produced good educational impact and social benefit (Ou 2014).

First, the project breaks through the choke point of education informatization development in the remote areas and realizes the educational equality. Second, the project promotes advanced education modes used in classroom teaching and improves the classroom teaching effect. Third, the project solves the problems of less qualified teachers and incomplete subject teachers supporting in the teaching sites. All teachers in the teaching sites can use the education resources from the national education resources public service platform to develop their teaching according to the subject needs. Fourth, the project optimizes the government's e-education, promotes the education informatization level of these teaching sites, and saves the cost of education. Fifth, and the most important point, the project injects new blood in the education informatization construction for remote areas and provides innovative developmental experience. The project is meaningful to promote balanced development of the education and realize education fairness and social justice (Yan et al. 2008).

6.3.2 The Problems of the Project

Because of the lack of equipment, relevant security investment, and project funds, the teaching sites can only purchase the necessary equipment and many places cannot equip computer desk, anti-theft device, or other facilities (Zeng and Gan 2014). There are inconvenient and potential safety hazards for use of equipment and routine maintenance. Digital education resources need to be further perfected. Teachers' application level is not high. The subjects of discipline curriculum resources in project equipment only include Chinese, math, and English, which lack the imperative subject digital education resources as music, PE, art, and so on. Meanwhile, the teachers' age structure and quality are various, which lead to great differences on the teaching effect. Many teachers only can do the basic playback operation to the curriculum resources video files and lack interactive methods with students.

6.3.3 Further Development Suggestions of the Project

6.3.3.1 Establishing Long-Term Application Mechanism of Teaching Site Project (Ke et al. 2014)

First, to strengthen policy and fund support is a priority. Second, establishing the reward system for using digital resources develops education. We can organize competition of teaching application, encourage and guide the teachers to use the digital resources in teaching, changing teaching methods, and improving the quality of teaching. Third, strengthen the development of resources and transmission.

The development of resources and transmission is key to the ongoing project application.

6.3.3.2 Formulating the Measure of Balanced Configuration for Teachers in Teaching Sites

The local government and education department should pay attention to the teachers' configuration in teaching sites, like changing the current situation of "stay" of aged teacher, introducing incentive measures, encouraging prominent teacher to get job in teaching sites, or increasing school teachers with volunteers and excellent teachers (Meng 2015). It is necessary to provide teachers guarantee for ongoing project of All Teaching Sites Cover with Digital Education Resources.

6.3.3.3 Forming Technical Support System for Teaching Application

We should establish a technical support system for the application of the project and strengthen the construction of support service system on task support, peer support, and social support for the project implementation and resources application (Lu 2014). It is necessary to formulate operable development scheme for the education informationization technical support service system for the teaching sites, explore the build idea and operation mode of the support service system for the teaching sites, establish feedback information system for teaching sites, organize the study of teaching case, carry out education resources application guidance, and help the teaching sites to work individually and complete the teaching mission efficiently.

6.4 Conclusions

In order to bridge the digital divide between the western remote rural area and developed area and improve the educational level of the teaching sites, MOE launched the Teaching Site Covered by Digital Education Resources Project following up the Rural Area Modern Distance Education Project. This project equips the teaching sites with quality digital education resources as teachers' needs, which facilitate the rural area to well and fully open the national courses and widen teachers' instructional horizon. However, there are still problems such as the update and maintenance of instructional equipment, application skills of digital learning resources, and the long-term mechanism of digital learning resources. Therefore, the collaboration of government, schools, and teachers is very important for full utilization of the Teaching Site Covered by Digital Education Resources Project.

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Chapter 7
An Overview of K-12 Digital Content in North America

Allison Powell

Abstract As online and blended environments are developed and grow throughout North America, there is an increased need for high-quality digital content. This chapter provides a brief description of the field of K-12 online and blended learning in the United States, followed by an overview of the types of digital content available to K-12 students and teachers. Next, the chapter discusses how content is developed along with the pros and cons of building your own content versus purchasing it from a publisher. Finally, an overview of quality standards that have been developed to assist schools and districts in evaluating digital content is shared. Resources for schools and districts are provided for developing, purchasing, and evaluating digital content.

Keywords Digital content · Online learning · Education technology · Blended learning

7.1 Introduction

Online learning in the K-12 environment is growing fast. It provides opportunities for students who would not otherwise have access to a world-class education. In the United States, online learning for students in grades K-12 is growing at a rate of 30 % annually, showing no signs of slowing down. With over 82 % of school

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districts providing these services and all 50 states providing opportunities, roughly 16 % of the entire K-12 population are taking advantage of these opportunities.

The International Association for K-12 Online Learning (iNACOL) was founded to increase global access to online learning. The organization facilitates collaboration among online learning professionals, advocates and educates policymakers and the public, researches best practices, and provides professional development opportunities. Since 2003, iNACOL's unique approach has helped over 5 000 000 K-12 students access high-quality courses through the Internet that they would not have had the opportunity to take in their local schools last year.

Online learning is expanding access to courses in K-12 education and providing a new network of highly qualified teachers to schools and students in underserved communities. Online learning has numerous benefits, including expanding course offerings, offering customized, and personalized learning, giving struggling students a second chance to master a subject through online credit recovery when they fall behind, and providing a rigorous, interactive learning model for schools with embedded assessments that are data rich (Wicks 2010). Online learning is providing the content, pedagogical approach, and integration of digital tools and resources that now support new models of teaching and learning, including blended learning, personalized instruction, portable, and mobile learning.

Blended learning is also emerging in North America and around the world. "It is not the same as technology-rich instruction. It goes beyond one-to-one computers and high-tech gadgets. Blended learning involves leveraging the Internet to afford each student a more personalized learning experience, meaning increased student control over the time, place, path, and/or pace of his or her learning.

The definition of blended learning is a formal education program in which a student learns:

(1) at least in part through online learning, with some element of student control over time, place, path, and/or pace;
(2) at least in part in a supervised brick-and-mortar location away from home;
(3) and the modalities along each student's learning path within a course or subject are connected to provide an integrated learning experience (Horn and Staker 2012)."

Blended learning occurs in a variety of venues and models. It occurs at the district and school level, where both online and face-to-face classes are offered. At the classroom level, blended learning can occur when online courses are supported with in-class instruction or instructional support. At the instructional level, blended learning incorporates digital tools and resources into content and assessments, building students' digital literacy skills as well as content knowledge. Blended classrooms enable schools to maintain continuity of learning during a pandemic or natural disaster, offer opportunities for personalization of classroom instruction, and offer students multiple pathways to learning.

Blended learning may incorporate online content in the form of a lesson, a single course, or an entire curriculum. The roles of teachers and students may be quite similar to their roles in a typical classroom, or they may change dramatically as learning becomes student-centered[1] as shown in the diagram below. A blended classroom or course that includes online instruction may expand learning beyond the school day or school year, or it may still be defined by classroom hours.

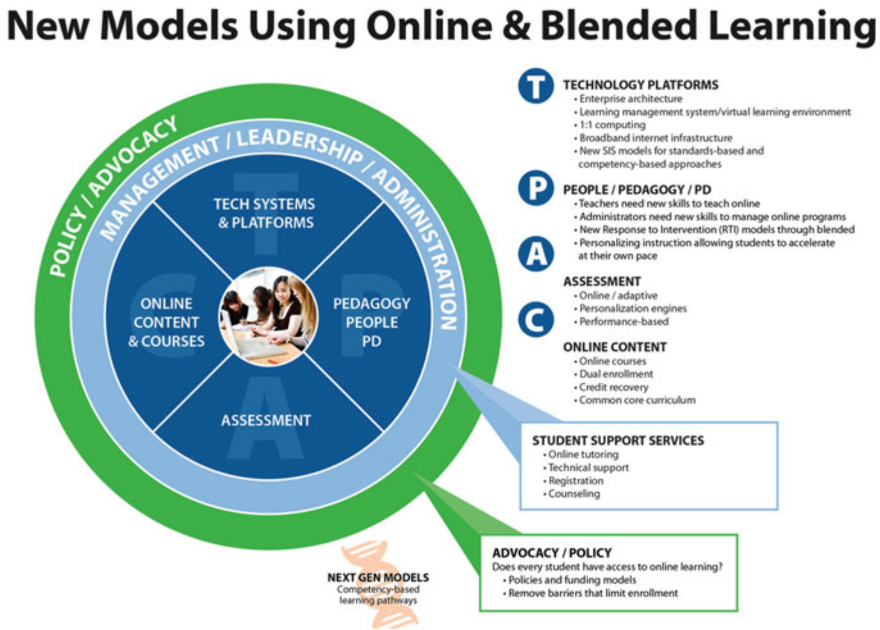
The main issue with online and blended learning in the United States is whether every student has access to the highest quality education available today. Research has been collected and determined that "on average, students seem to perform equally well or better in online learning courses" (North Central Regional Education Laboratory, Learning Point Associates 2005). Through online learning, we can expand educational offerings, options, and opportunities to every student through this new delivery model, over the Internet. Online learning also helps to ensure that every student is college-ready and work-ready. With 20 % of college students taking an online course, part of college readiness is leveraging a new delivery model using online learning to increase access to courses and help students graduate from high school. With 30–50 % of workforce training done online, having students learn online in high school helps prepare and be more aware of options and opportunities available to them for success in college and in life.

Individual schools, districts, and state departments of education have been developing Quality Online Courses for students within their states and beyond their borders for over 20 years. Twenty-six states have state virtual schools offering courses statewide, more than 70 % of pubic school districts offer online courses (Sloan-C 2009), and 30 states allow for full-time cyber charter schools (Watson et al. 2014).

7.2 Digital Content

When developing online and blended programs, school administrators should take into consideration: the technology, the people (teachers, administrators, and the professional development needed to support them), as well as assessments and content. Below is a graphic that shows how each of these pieces works together to support student-centered learning environments.

[1]Watson et al. (2010).



New Models Using Online and Blended Learning. Patrick (2012). Creative Commons License

For the purposes of this chapter, we will take a look at the online content piece of online and blended learning. Advances in technology provide a new distribution model for education institutions to offer online courses and degrees. Online courses are engaging for students (and can provide a wealth of data for administrators and teachers). Online teaching requires training in new instructional strategies and resources to enable personalization, greater interactions with students, and new models of student support—including multimedia applications and real-time and threaded conversations using the Internet.

The online curriculum landscape varies widely and covers the entire range of educational options. This section helps new programs make sense of the different types of courses, the ways in which courses can be developed or licensed, and how to evaluate the quality of digital content.

Many school districts use a Learning Management System (LMS), which is the core technology piece for operating an online learning program. The LMS is *the set of tools that houses course content and provides the framework for communication between students, teachers, and parents* (Watson and Gemin 2009, p. 18). Within the LMS, teachers can create and upload digital content to share with their students.

In many ways, digital content is merely a set of tools for teachers and students to use for a wide range of communication and interaction. Together, these tools provide a flexible means of delivering courses of any kind. There is no one right kind of online course, and describing the range of online courses can be at least as complex as describing the kinds of courses presented in face-to-face environments.

Throughout North America, there are four common types of digital content being used in K-12 online and blended courses. These include supplemental resources/lessons, learning objects, e-books, and full courses. A combination of these types of digital content is used by the majority of online and blended schools and programs.

7.2.1 Supplemental Resources/Lessons

Supplemental resources and lessons are the most basic type of digital content. They may include digital content resources such as videos, podcasts, website URL's, games, etc., which can be used to supplement a teacher's lesson in the face-to-face or online course.

Sometimes, a teacher's lecture or the textbook may not be sufficient in explaining a specific concept for every student in the class. In these cases, supplemental resources are most often used to teach a various concepts in a different way than the teacher presented the material to the class. Students can choose from a variety of resources and lessons to learn the concept in order to demonstrate mastery. Once the student has mastered that skill or competency, the resource is no longer needed for that specific course.

A teacher and even individual students usually find these resources on his or her own to offer students an alternative way to learn a concept. Some may be developed and uploaded to the Internet by the teacher; however, the majority of these resources can be found through a simple web search. Many of these resources are free to use on the Internet, but in some cases, they may require a subscription or one-time fee to access them.

In addition to supplemental resources, many teachers post their lessons online for students to access in the classroom or at home. These lessons may include supplemental resources; however, many teachers just post the learning objective and assignment, requiring the individual students to search for their own resources to learn the concept.

7.2.2 Learning Objects

Learning objects is "a collection of content items, practice items, and assessment items that are combined based on a single learning objective" (Cisco Systems 1994). Learning objects provide smaller, self-contained, reusable units of learning. Common supplemental resources are grouped together to form a unit of study into a module, which includes instructional content, practice, and assessment.

Teachers find and/or develop supplemental resources to create a unit of study to share with individual, groups of, or entire classes of students. Teachers can customize learning objects to meet individual student needs. Students can access these units at home or school. Most learning objects are used to teach an entire unit of study, while others can be used to teach specific parts of a unit, usually replacing or supplementing textbooks and teacher lectures.

Within the LMS, teachers can curate a variety of supplemental resources to create a learning object to share with their students. Teachers can create a variety of learning objects customized for individual students, a small group, or an entire class. Students then access these resources and complete the assignment and assessment within the LMS, and receive feedback and new content from the teacher once the unit has been successfully completed.

7.2.3 e-Books

An e-book is an electronic version of a printed textbook. E-books consist of text, images, or both and can be read on a computer or mobile device. Several textbook publishers have digitized their textbooks and now offer schools both a print and digital version of the books.

E-books replace traditional textbooks and several e-books can be accessed from a single mobile device allowing students to easily transport several books to and from school.

The majority of e-books are in a format that cannot be customized or changed to meet different student needs. They are essentially a book, but in a digital format. However, as digital content advances and becomes more interactive and engaging, we are beginning to see more customizable e-books.

7.2.4 Fully Online Courses

Entire semester or year-long courses are also offered in digital formats. These courses pull together a combination of supplemental resources, learning objects, and e-books to create an entire course. Full courses can consist of basic files (pdfs, videos, links, etc.) uploaded to a Learning Management System in a sequential order all the way to a fully game-based course where students must fully engage with the content to master the concepts. Students enrolled in fully online courses can take these courses at their traditional schools or away from school, working with their teacher remotely.

Students choose to enroll in fully online courses for a variety of reasons. Their traditional brick-and-mortar school may not offer a specific course that a student wants to take (specialized courses that are hard to staff), to make up a course they previously failed, scheduling issues, to graduate early, etc. These online courses replace the traditional classroom and allow students to access learning options they would otherwise not have.

Schools can purchase these courses from publishers or have teams of educators to develop them in house. Full digital courses begin with a syllabus and a list of the standards and objectives associated with the specific course. Some courses will be developed around a theme or game, while others are more text based.

Schools and districts must decide if they are going to buy or build their own courses. Many publishers have developed a fully online curriculum for grades K-12, while others focus on specific subject areas or grade levels. Content publishers tend to have more money to invest in developing courses, but can limit the teacher's ability to supplement the content.

With advancements in Learning Management Systems technology, content is becoming more adaptable to students individual learning needs. Individual student playlists are becoming more popular within fully online and blended courses. Students are assessed at the beginning of the course, and based on their assessment, the teacher and LMS can assign a "playlist" for the student based on the skills and concepts he or she needs to master. These playlists are not only based on the assessments, but also the students' interests and give the students more choices in how and what they are learning.

7.2.4.1 Types of Fully Online Courses

Online course content is available for core courses, credit recovery, Advanced Placement®, International Baccalaureate®, and a wide range of electives. Online project-based schools are also on the rise. This section describes various issues and characteristics to look for when selecting such content.

7.2.5 Core Courses

Naturally with core courses, you have the largest selection of providers and the largest variety of characteristics and quality. Major curriculum providers generally have a full range of courses in the core subject areas of English language arts, math, social studies, and science.

These courses are typically based on national standards, such as the Common Core, or in some cases, the state standards of the company's home state. Courses are usually designed to be equivalent to a semester course and to fit into a typical semester-based school calendar.

7.2.6 Credit Recovery

Credit recovery courses are designed for students who have previously taken a course in the specific subject, but were not successful. Although there are no universally agreed-upon standards for credit recovery courses, they tend to require less time than core courses for students to complete. These courses often include pretests designed to assess the knowledge the student gained from their previous experience so that they can use the credit recovery course to merely fill in the gaps.

7.2.7 Advanced Placement® and International Baccalaureate®

Both the College Board's Advanced Placement® (AP®) program and the International Baccalaureate program have approved online courses that meet the same standards as approved face-to-face courses. For AP® courses, online learning programs undergo an audit process that is identical to the process for face-to-face courses in bricks and mortar schools. The College Board has approved AP® courses in all of its subject areas, including science.

7.2.8 Electives

A huge variety of elective courses are available online. A wide range of world languages, sciences, social sciences, technology, and business classes allow even the smallest or most remote schools to offer dozens of courses. Career and technical education, and even driver's education, are available. Careful selection of a suitable licensure model can make such a robust catalog affordable.

7.2.9 Project-Based and Other Alternatives

Content and programs focused on a particular learning strategy or student audience are growing as well. The landscape includes options such as online project-based schools in which students design their own learning, religiously affiliated schools, and even a school designed specifically for gender and sexuality minorities.

Many of these programs welcome partnerships with other schools, allow part-time students, resell specific courses, or otherwise allow more traditional programs to tap into their unique offerings (This section was adapted from iNACOL 2008).

7.3 Digital Content Development

Schools and programs wanting to implement more online and blended learning must first ask should your program build your courses, buy them, or use a combination of both? The answer to this complex question depends primarily on the available resources, the skills of your staff, and your timeline. This section outlines that the variety of ways content is developed in North America, as well as the pros and cons of both building and buying or licensing courses.

Because many schools and district's curriculums are already standards based and many places have established course syllabi, online course development can be less of a challenge than if these things are not already in place. If these things are in place, then it is just a matter of applying current online learning best practices based on the literature and instructional experiences to already developed course objectives.

7.3.1 Individual Teachers

In many cases, individual classroom teachers create their own digital content. This can be as simple as recording themself giving a lecture, to posting a lesson online, to even developing a full online course on their own.

One of the biggest challenges in having individual teachers creating digital content is in assisting teachers to use the tools to create the content. In the early days of developing digital content, teachers had to learn to use web design tools such as *Dreamweaver* and *Photoshop* in addition to some HTML as the tools available were not as easy as dragging and dropping content into the LMS as they are today.

Another challenge for teacher's developing digital content on their own is that many teachers know the content and best practices for designing face-to-face content well, but sometimes that does not transfer well into the online format. Professional development in instructional design as well as using the technology is necessary for teachers to be successful in developing digital content on their own.

Finally, compensation for teacher's developing digital content must be considered, in addition to who "owns" the content. If a teacher is being paid to develop the content for their students, the school, or the district, in most cases, the entity that paid for the development of the content has all rights to the content.

In many places, Open Educational Resources (OER) are becoming more popular and available. "OER are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use and re-purposing by others. Open educational resources include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials, or techniques used to support access to knowledge" (William and Flora Hewlett Foundation 2002). More and more teachers are seeing the value in sharing the digital resources they have created with other teachers around the world.

7.3.2 Teams/Consortium

In many ways, creating a fully online course is similar to writing a textbook. It is a major undertaking and must be considered carefully to ensure a quality educational product for students. Teams, including a content expert, an instructional designer, and a web developer, work together to build these courses. Schools and districts that develop their own content in teams and consortia also have a clear process, including budget, timeline, and design standards. The process can be both challenging and rewarding. This section is not a complete how to guide for course development; it is intended to provide just a general overview of a typical process.

7.3.2.1 The Team

Effective course creation is always a team process. No one person has all the skills necessary to create a high-quality course. At the very least, a content expert, an instructional designer, and a web developer are the members of this team.

1. *A content expert*: This might be a teacher or an outside expert who understands the content at a deep level. This person should have skills and knowledge that goes far beyond a typical teacher and preferably is familiar with multiple textbooks so that wise decisions can be made that do not merely mimic any particular text. Content experts must also have a strong working knowledge of relevant state and national standards.
2. *An instructional designer*: Instructional design does not mean basic lesson planning. Principles of effective instructional design are rarely taught in teacher preparation programs. Such skills are generally reserved for focused graduate programs. Your instructional designer for online courses is not a teacher, but rather someone who is experienced in the principles of design and the wide range of tools and techniques available in the online environment. The instructional designer works closely with both the content expert and the web developer to insure integrity of the content and design.
3. *A web developer*: Effective course development goes beyond putting up a few files into the LMS. When developing an online course, integrating a range of graphics, animations, videos, and sound clips to engage your learners and make the most of the online experiences is essential. The web developer understands principles of layout, file management, compression, and other critical features that make the content efficient and usable. The web developer also needs to

understand the W3 design standards to ensure that course complies with Section 508.

Other potential team members can include the following:

4. *A project manager*: Depending on the size and complexity of the project, schools may wish to have someone assigned to oversee the course development and manage all aspects of the process.
5. *A content editor*: The content editor is another content expert that checks and verifies the accuracy of the content expert's work.
6. *A text editor*: The text editor is a writing expert who ensures that the entire course is clear, readable, and written at the appropriate reading level.
7. *LMS manager*: The LMS manager is the person in the organization responsible for maintenance and installation of the LMS. When it comes time to create a course shell and install the course in the LMS, the LMS manager will work with the rest of the team to make sure the final installation functions as designed, both technically and instructionally.

7.3.2.2 The Timeline

How long does it take to develop a fully online course? Although there is not a single, specific answer, many schools and districts have shared that it takes about 12–18 months for a course equivalent to a full year's content. Consider the following steps:

1. Project approval
2. Content research
3. Content writing
4. Instructional design
5. Multimedia purchase or development
6. Web development
7. Installation into the LMS
8. Preliminary approval
9. Piloting with students
10. Revision
11. Final approval
12. Launch

7.3.2.3 The Budget

Perhaps even more complex and variable than the timeline, the budget controls the pace, the size and caliber of the team, the amount of multimedia, and ultimately, the quality of the course.

Some commercial companies spend as much as $250 000 or more to develop a semester course. Rarely is that feasible for those schools and districts who wish to develop their own. Using Open Educational Resources (OER) and other readily available low-cost content, developers can reduce costs significantly.

These steps vary considerably in length, and some organizations may require additional approval steps. Not all programs choose to pilot courses with students prior to launch, but instead, consider the first time the course is offered to be the course pilot. Eliminating the pilot phase can save time, but may provide students with a sub-par experience. Of course, the quantity of content, complexity of multimedia, and level of quality all impact the pace of development. Increasing the number of team members can help speed up the process, but would generally require a larger budget (This section was adapted from iNACOL 2008).

7.3.3 Companies

When online and blended learning first started in the mid-1990s, teachers, schools, and districts had to develop their own digital content if they wanted to use it with their students. There were no companies selling content at that time and it was expensive and difficult to find professional development to prepare teachers and teams to do it on their own. Now, a wide variety of publishers and content providers develop individual courses as well as full K-12 curriculums.

These companies use the team approach and have to invest hundreds of thousands of dollars into research and development as well into the development of each semester course. A wide range of options exists for licensing courses, from per semester tuition programs to perpetual licenses to comprehensive service providers. Often programs mix and match license types to maximize cost effectiveness for high-enrollment and low-enrollment courses. This information does not replace the need to shop carefully and be sure you understand the models that your vendors present.

7.3.4 To Build or Buy Digital Content

There are excellent reasons why you might want to create your own courses, and equally excellent reasons for purchasing or licensing them from a provider. In some cases, programs choose to purchase or license core courses but develop their own particular electives to meet unique needs. The following table shows the pluses (+) and minuses (–) of both approaches (Table 7.1):

Finally, the courses you license must be able to function smoothly in the school's or district's LMS. The selection of courses and the learning management

Table 7.1 Pros and cons of building versus buying online courses

Issue	Build	Buy
Initial cost	– Large upfront investment prior to enrolling students	+ Multiple license models can allow for low initial costs
Ongoing cost	+ Ongoing costs limited to course maintenance and updating	– Depending on the licensing model (s) selected, ongoing costs can be nearly as much as initial costs
Content and design flexibility	+ School has total flexibility over content, instructional design	+ Some licensing models allow for course customization
	– Ongoing course maintenance and revisions required at local level	– Ability to customize courses in content or design is inherently limited
	– High cost of multimedia development may limit design options	
Decision making	– Every component of the course needs to be thoughtfully designed	+ Decisions about most details are already made. Decision-making process is limited primarily to which courses will be licensed using which licensing models
Timeline	– Roughly 12–18 months to develop a course	+ A large number of courses readily available
Skill development	+ Develops district skills in content writing, online instructional design, technology and other skills	– May develop online instruction skills. Does not generally develop writing or design skills
Risk	– Higher risk in that the larger initial investment does not guarantee a successful course will be produced	+ Lower risk due to lower initial costs, the ability to start with just a few enrollments, and ability to switch course vendors if necessary
Curriculum uniqueness	+ Any imaginable course can be developed	– Courses available are those designed for large, nationwide consumption. Options in some elective areas can be quite limited
Copyright ownership	+ District/school owns the course, can resell it and market it as a unique offering	– District/school does not own the copyright and generally cannot redistribute or resell
Professional development	– Requires wide-ranging professional development on content, design, technology, and instruction, including W3 design standards	+ Professional development is focused on instruction and the nuances of the particular course

iNACOL (2008)

system in which they are housed is a critical step in the decision on whether to build or buy digital content. Deciding on a platform and the content can sometimes be a *chicken or the egg* question. Some schools and districts choose the platform first and then only select content that will run on that platform, while other programs choose the content first and then limit their selection of platforms that will host the selected content. Yet, other programs attempt to make these decisions simultaneously. Regardless of the strategy used, there are issues related to several aspects of both the courses and the LMS, including questions about technical details, content, and cost.

The compatibility of the content with the LMS includes both technological and educational aspects. The tools available for interaction, the content file structure, and the function of the content's assessments are all critical to a system that works well for students and teachers. Major content providers will have a list of LMSs that work well with their content, and they should be able to identify any known issues related to compatibility between their content and the LMSs that you are considering (This section was adapted from iNACOL 2008).

7.4 Quality Assurance

Not all digital content and fully online courses are created equally. As is true with any other type of product or publication, there are high-quality and low-quality examples. Different types of content serve different purposes and take different instructional approaches. In ways similar to how a school's curriculum team reviews textbooks, a team should review online course selections to ensure that the course will meet the program's needs. Both the criteria used and the processes employed are important for ensuring a quality product that serves students and teachers well.

iNACOL has published National Standards of Quality for Online Courses. This document consists of five standards, each with multiple criteria. Although some of the criteria may not apply to all situations, this document provides the best available starting point for digital curriculum review.

National Standards for Online Course Quality is designed to provide states, districts, online programs, and other organizations with a set of quality guidelines for online course content, instructional design, technology, student assessment, and course management. The initiative began with a thorough literature review of existing online course quality standards followed by a survey offered to representatives of the NACOL network to ensure the efficacy of the standards adopted. These guidelines were meant to be implemented and monitored by schools, districts, and/or organizations, as they reserve the right to apply the guidelines according to the best interest of the population for which they serve.

Quality and accreditation are key issues for K-12 online learning and digital content. iNACOL has established National Standards of Quality for online courses, in addition to national standards for quality online teaching, online programs, and blended teaching. iNACOL is working with states, districts, and regional accreditation agencies to ensure that high-quality online programs are recognized and accredited appropriately. Universities are also working with the regional accrediting agencies to ensure quality and accreditation of their programs.

The committee of experts who developed the online course standards has also developed a diagram of the Defining Dimensions of Blended Learning to assist in the understanding of how quality online content and digital resources and tools can be implemented within a blended school or program. This diagram specifically focuses on the unique characteristics across blended learning programs. From minimally using online content and digital tools and resources in a face-to-face classroom to a cohesively designed blended learning model, blended learning is emerging in a variety of forms. Blended learning trends show that implementations of new models look less like older models of distance learning and are emerging toward personalizing digital learning for each individual student at scale.

The focus of this diagram is on illustrating the variety of instructional models for blended learning. Blended learning can and does happen in a school model and there are specific operational issues an administrator must be aware of such as various policy issues, how funding follows the student, and technical issues of how administrative tools connect and work together; however, in this graphic we chose to focus on the course/instructional level.

The graphic of the Defining Dimensions of Blended Learning Models tries to draw out what the possibilities are in terms of the continuum of blended instructional approaches. iNACOL is not making a value judgment on what is appropriate and what should or should not be used in a blended learning model within this graphic. The goal of this graphic is to show how blended models are being implemented from the early stages to mature, fully developed blended programs. In the original version of the iNACOL National Standards for Quality Online Courses (2006), iNACOL identified key criteria for course quality standards and since then has revised these standards based on surveys of best practice in the field. iNACOL's goal is to provide a working framework of the characteristics of emerging blended learning and a multistage process of defining high-quality blended learning in the future.

Each of the dimensions impacts the role of the teacher across a variety of implementations. iNACOL divided the dimensions into categories to show characteristics of the instructional model, student-centered approaches, and operational dimensions.

THE DEFINING DIMENSIONS OF BLENDED LEARNING MODELS

Characteristics Driving the Changing Roles of Educators		LEVEL OF BLENDED LEARNING: Less Online Instruction	More Online Instruction	Mostly Online Instruction
Characteristics of Instructional Models	INSTRUCTIONAL MATERIAL LEVEL	Learning Object / Unit/Lesson	Single Course	Entire Curriculum
Characteristics of Instructional Models	INSTRUCTIONAL RESOURCES	Course **minimally uses digital content**, resources, and tools to supplement instruction	Digital content, resources, and tools **expand and enhance** the curriculum and content	Use of digital resources and tools **are integral to** content, curriculum and instruction
Characteristics of Instructional Models	ASSESSMENT	Whole-class assessments, used primarily in the classroom, during the school day as the primary means of feedback	A combination of traditional and online assessments are used inside and outside the classroom	Greater amount of digital, real-time data and feedback allow for individualized instruction
Characteristics of Instructional Models	COMMUNICATION (Student / Teacher & Student / Student)	Occurs primarily synchronously and in the physical classroom	Is a mixture of synchronous & asynchronous and may be in the physical classroom or online	Occurs primarily asynchronously and online or from a distance
Student-Centered Instruction	ATTENDANCE REQUIREMENTS	Students are required to attend a physical classroom 5 days a week	Students attend a physical class-room less than 5 days a week and work online at other times	Students have flexible physical classroom and/or location attendance requirements.
Student-Centered Instruction	STUDENT LEARNER'S ROLE	Student is primarily the recipient of teacher provided instruction. Teacher sets day-to-day pace.	Student takes active role in learning with reliance on digital content, resources and tools. Student has more control of own pace.	
Student-Centered Instruction	INDIVIDUALIZATION OF INSTRUCTION	All students expected to complete same instructional pathway	Students engage with digital content to customize their instructional pathway	Students engage with digital con-tent and have multiple pathways that are competency-based and not tied to a fixed school calendar.
School Considerations	INSTRUCTIONAL SUPPORT MODELS	"Direct student learning" through traditional teacher roles and staffing models	"Facilitate student learning" through a team approach with a significant reliance on technology-based tools and content	"Coordinate student learning" through the expanded use of technology-based tools and content, as well as the effective use of outside experts and/or community resources
School Considerations	INSTRUCTION SCHEDULE AND LOCATION	Fixed daily schedule, instruction primarily in physical classroom	Mixed schedule of online and physical instruction	Highly flexible schedule, with instruction is possible 24x7. Learning centers support instruction.
School Considerations	ACCESS TO ACADEMIC STUDENT SUPPORT	Support is school-based, and provided primarily by the teacher during the class period.	Support structures (e.g. online tutoring, home mentors, and technical support services) in place 24x7, in addition to teacher support.	
School Considerations	TECHNOLOGICAL INFRASTRUCTURE	School or classroom based with students using shared classroom computer resources. Access to infrastructure ends with class period.	Available across school campus with students checking out computers from a lab or bringing their own. Access to infrastructure is during school hours.	Available on and off campus with students using their own device. Access to infrastructure is 24x7.

The Defining Dimensions of Blended Learning. iNACOL (2011). Creative Commons License

iNACOL hopes that this diagram will serve as a tool for educators, administrators, and policymakers to understand the essential elements of blended learning in order to make informed decisions about implementing blended programs. These leaders and innovations in online and blended learning continue to build a pathway to change the landscape of how we think about learning while increasing student opportunities for a new community of learners.

iNACOL included this graphic within the National Standards for Quality Online Courses to provide those new to the field with a better understanding of how online content and digital tools and resources can be implemented in both face-to-face classrooms as part of a blended learning environment as well as within a fully online course. As the committee was refreshing the course standards, the topic of developing a separate set of standards for blended courses was discussed.

The committee and iNACOL believe that all online content, however, it may be implemented, should meet the standards in this document, and hope that the graphic above will serve as a guide to implementing quality blended learning models for our students [This section was adapted from iNACOL (2011)].

7.5 Conclusion

Education is critical for empowering youth to gain the knowledge, skills, and dispositions to be successful in college careers and in a new global economy. The United States is falling behind other countries around the globe in preparing students to compete. UNESCO reports "Students in the United States made scant headway on recent global achievement exams and slipped deeper in the international rankings amid fast-growing competition abroad. (PISA 2014) American teens scored below the international average in math and roughly average in science and reading, compared against dozens of other countries that participated in the 2012 Program for International Student Assessment (PISA), which was administered last fall. U.S. Education Secretary Arne Duncan characterized the flat scores as a 'picture of educational stagnation.'"

A recent publication by the World Economic Forum titled, *Education and Skills 2.0: New Targets and Innovative Approaches*, underscores "the critical importance of education" and highlights "what can be done to ensure that all people around the world can benefit… [the real] value-add is on conceptualizing and describing innovative, plausible, scalable, compelling and high-impact solutions that will improve access to education," and strengthens educational outcomes and close achievement gaps.

The world is rapidly changing, and we must ensure that our education system prepares students to be successful in a future that continues to foster innovation and change quickly. Empowered and emboldened by the changes underway, we must take a serious step to hold students to high academic standards, rigor, reframe quality, accountability, and improve educational opportunity and increase access to educational opportunities to ensure that each and every student is prepared for their future with a student-centered, world-class education.

The field of online and blended learning holds tremendous potential for improving the learning and achievement of all students. Digital learning helps to address many critical challenges facing today's education system –identifying gaps in student proficiency, providing personalized content and tools for teachers to rapidly intervene with individualized instruction, offering new pathways for preparing every student to be college-ready and career-ready, providing new distribution models through online courses to enable teaching anytime, any place, expanding content resources and providing more relevant and engaging curriculum, and bridging the geographic and economic barriers limiting many students' access to high-quality instruction.

Blended, digitally enabled learning has the ability to support personalized learning to meet each student's individual needs and interests through competency-based pathways and new learning models. Technology should not be layered or integrated over old models, but rather approached from a systems redesign perspective for creating new instructional models that are student-centered, mastery-based, offer greater flexibility and personalization for students, provide new staffing models and roles for educators, and can dramatically improve student outcomes. It is very difficult for one teacher in a classroom of twenty-five students and a single textbook to personalize instruction for each student's needs. With technology and digital content, teachers are empowered to personalize learning and address each student's individual needs. The systemic shift toward personalized learning was enabled by new blended model leverages technology to allow greater personalization, while targeting each individual student's needs for learning more rapidly, providing immediate responses to intervention, offering targeted support when needed, and allowing students to demonstrate deeper learning competencies, advance based on competency and accelerate. These new models will allow student learning to be more flexible to address each student's needs for differentiation, and support to both address gaps and accelerate learning—holding all students to high college and career-ready standards to prepare them for success.

Digital learning, in the form of blended and online education, is fundamentally changing what is means to "go to school" for millions of students in North America and around the world. No longer is "school" defined solely by a physical space, or classrooms with desks and a teacher at the center. Nor does the curriculum that the student is required to navigate have to be a one size that fits all students model, where assessments and data are used more as an autopsy of a student's performance rather than a tool for making immediate modifications to meet students' needs and abilities. Through advancements in technologies, improved administrative and teacher preparation programs, and greater access to curriculum resources that are engaging, interactive, and rooted in capturing student performance data, American schools have the ability to personalize learning and focus on each student's learning gains and competencies like no other time before now.

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Part IV
Promoting e-leadership by Using ICT

Chapter 8
Data-Driven Decision Making for School Leadership: A Critical Analysis of Supporting Systems

Stylianos Sergis and Demetrios G. Sampson

8.1 Introduction

Schools are complex adaptive systems comprising a wide range of interrelating agents including (among others) the leaders, the teachers, the students and their parents, infrastructure, as well as policies (Lai and Schildkamp 2013; Trombly 2014). These factors interplay in an intertwining manner on two main school institutional layers, namely (a) the *micro*-layer, which focuses primarily on the teaching, learning and assessment processes, and (b) the m*eso*-layer, which focuses primarily on the organizational management and development of the school (e.g., human resources, financial and infrastructural management) (Breiter and light 2006; Kaufman et al. 2014).

In this context, (school) Complexity Leadership is primarily addressed at orchestrating such complex adaptive systems (Schneider and Somers 2006). This approach allows for a more distributed standpoint for leadership, where strategic planning is not solely devised by a single agent (administrative leadership), but is also the result of the interactions of other system agents such as the students, teachers and infrastructure (adaptive leadership) (Lichtenstein et al. 2006; Uhl-Bien et al. 2007). Therefore, towards capturing these interactions and generating informative feedback loops for influencing school system emergence, it is critical to

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enable and sustain a constant flow of institution-wide educational data (Uhl-Bien et al. 2007)

Following this approach, school leaders, namely principal leaders and teacher leaders (OECD 2013), are recognized as a highly influential agent for school organizational performance (Sun et al. 2013; Wallace Foundation 2013; Hauge et al. 2014), both in terms of high-quality educational outcomes (Robinson 2007; European Commission 2012), as well as for sustaining school organizational improvement and staff development (European Commission 2013; Liou et al. 2014). Moreover, these processes are becoming increasingly challenging considering the global push toward school autonomy and accountability, which assign more degrees of freedom (and, thus, responsibility) to school leaders (Knapp and Feldman 2012; West et al. 2014).

Therefore, it is evident that school leaders face complex multicriteria decision-making problems, which require holistic and highly granulated support mechanisms (Olson 2008). In response to this, data-driven decision making in education has received an increasing level of attention and emphasis, on a global scale (Knapp et al. 2006; Park and Datnow 2009; Lai and Schildkamp 2013). As a process, similar to the standpoints of Complexity Leadership, it refers to the collection, analysis, and interpretation of institution-wide data towards generating feedback loops and insights for informing leadership in educational settings (Mandinach 2012). Employing data-driven decision-making processes is considered to be instrumental toward effective school organizational leadership and development (Lai and Schildkamp 2013; Gill et al. 2014; Schechter and Atarchi 2014).

However, the actual exploitation of these institution-wide feedback loops from school leaders is usually hindered due to several reasons including time constraints and the required competences of the school leaders to analyze the collected data and identify solutions (Marsh and Farrell 2014). Moreover, the level of availability and quality of institution-wide data collection and processing greatly influences the capacity of the leaders to engage in their school leadership tasks (Marsh et al. 2006; Ikemoto and Marsh 2007). Considering these impeding factors, and taking also into account the facts that (a) schools are complex adaptive systems with a wide range of interrelating agents in both institutional layers contributing to their overall state of performance (Synder 2013) and (b) school autonomy and accountability are being globally pursued and promoted (Hooge et al. 2012; OECD 2014a), a need is identified for school leadership decision support systems (SL-DSS) that will address the core school leaders' tasks and will effectively facilitate their decision-making processes based on the provided institution-wide feedback loops (Kaufman et al. 2014).

Under the light of the above, the contribution of this book chapter is twofold, namely (a) to perform a critical quantitative analysis of existing SL-DSS, in terms of their capacity to adequately support a set of core school leadership tasks and their respective data-related needs, as the latter are defined in this book chapter in the form of a School Leadership Task framework (SLT) and (b) exploiting the previous analysis' results, to gather insights and draw conclusions which could potentially drive future implementations of SL-DSS toward providing more effective data-driven decision-making affordances for school leaders.

The remainder of the book chapter is as follows. Section 8.2 defines the background of this work. More specifically, it reviews the landscape related to school (complexity) leadership as well as the related core school leadership tasks and their institution-wide data requirements. The aim of this section is to formulate the SLT for driving the critical analysis of SL-DSS. Section 8.3 presents the methodology and results of the critical analysis of 70 existing school leadership decision support systems, benchmarked against the developed SLT. Finally, Sect. 8.4 presents the conclusions drawn from the previous analysis, toward identifying recommendations for future SL-DSS that will facilitate school leaders in performing the full spectrum of their tasks and engaging in effective school organizational learning.

8.2 Data-Driven Decision Making: The School Leadership Context

8.2.1 School Complexity Leadership

8.2.1.1 Definition

In international literature, there are different and sometimes, contradicting, definitions of School Leadership derived from the different perspectives of Leadership as well as, the different Educational Policies (Yukl 2002; Leithwood et al. 2006; Bush and Glover 2014). A commonly cited definition of school leadership is "a process of influence leading to the achievement of desired purposes, requiring successful leaders to develop a vision for their schools based on their personal and professional values" (Bush and Glover 2003). Therefore, school leadership can be regarded as a "social" influence process which involves (a) the formulation of a vision for (holistic) organizational progress from leader(s) and (b) the continuous sharing and "influencing" of other individuals or groups toward achieving this vision (Bush 2008; Park and Datnow 2009; OECD 2013).

A clarification should be made at this point, regarding the terms "school leadership" and "school management" (and "administration") given that it is common for the two terms to be used interchangeably as identical (OECD 2013). The term school management (and administration) mainly refers to tasks related to the maintenance of present operations and resources of the organization. The term school leadership has emerged, first as an alternative, mainly referring to tasks related to vision building, strategic planning, and the creative formulation of action plans for school organizational improvement (Bush and Glover 2014). However, it is becoming increasingly evident that effective and holistic school organizational development requires both these two capacities as equally important and, in fact, complementary (OECD 2008, 2013; Bush and Glover 2014). Therefore, adhering to this notion, this book chapter will adopt an overarching conceptualization of school leadership, which will, however, fully engulf the concept (and related tasks) of school management. More specifically, school leadership tasks considered in this book chapter will include both management tasks (as they were previously presented), as well as strategic organizational planning for changes.

Furthermore, the concept of school leadership has undergone another transformational procedure in terms of (a) "who" the school leader is (power balance) and (b) "what" specific area of the school organization the school leader is explicitly leading (Bush and Glover 2014). More specifically, initial forms of school leadership advocated in favor of a sole power position (e.g., the individual principal) which was responsible for leading the school as an educational organization addressing specific function areas, e.g., overseeing the teaching practices within the classroom (instructional leadership) or orchestrating the managerial tasks of the school (managerial leadership) (Hendriks and Scheerens 2013; Bush and Glover 2014).

However, such restrictive conceptualizations of school leadership have been superseded by novel approaches, mainly due to the fact that they have been attributed with poor organizational performance (Leithwood et al. 2006; Oswald and Engelbrecht 2013). More specifically, a paradigm shift has gradually occurred promoting more distributed leadership paradigms. These approaches advocate for (a) tipping the power balance toward more apportioned leadership which engages other school agents such as teachers (Bush and Glover 2012; Gurr and Drysdale 2013) and thus, (b) expanding the range of organizational function areas being subject to scrutinizing leadership toward a more holistic approach (Leithwood et al. 2006; Bush and Glover 2012; Dimmock 2012).

In this context, Complexity Leadership posit the notion that strategic planning and outcomes are not solely devised by a single agent (administrative leadership), but are also the result of a range of actions and interactions from other system agents such as teachers (adaptive leadership) (Lichtenstein et al. 2006; Uhl-Bien et al. 2007). Leadership needs to be shared to be effective (OECD 2013). The administrative leadership strand is related to the "topdown" leadership processes, focusing on managerial aspects (Harris 2010; Uhl-Bien et al. 2007). Examples of administrative leadership, which is usually performed by the principal leader, are strategic planning for the organization, allocation of resources and coordinating staff professional development activities (OECD 2013). The adaptive leadership strand, which is closely related to the distributed leadership standpoint, refers to the adaptive interactions of the school system agents (a key strand of which are the teacher leaders) that emerge from practice and not strictly as a result of authority (Uhl-Bien et al. 2007). Utilizing both strands can offer higher levels of granularity for the leadership team in both (a) formulating more informed strategic school organizational plans, as well as (b) orchestrating the plans' realization. More specifically, the *formulation* of holistic strategic organizational plans can be enhanced by combining the feedback loops from the range of micro-layer educational data to which teachers have better access to with the meso-layer school data which are available to principals (Day and Harris 2002). The orchestration of the plans' realization can be more effectively performed within a distributed, teacher-inclusive leadership model by allowing the leadership team to have a more detailed overview of the day-to-day progress and the potential shortcomings that occur within each institutional layer of the school (Mulford 2003). Finally, despite an initial division of tasks among the two leader types (i.e., teacher leaders being mainly focused on micro-layer leadership and principal leaders being mainly focused on meso-layer leadership), there is an increasing trend toward blurring and intertwining the boundaries between each leader type's tasks (Firestone and Martinez 2009). For example, teachers are assigned with tasks of managing staff professional development for their peers (Gonzales and Lambert 2014) or principals are engaged with the design and/or orchestration of student learning activities (Copland and Knapp 2006).

Based on the above, this book chapter adopts the conceptualization of school leaders as a dualistic concept, comprising the principal leader strand and the teacher leader strand (Leithwood et al. 2007; Crowther et al. 2009; OECD 2008, 2013). The following section builds on this conceptualization in order to present a set of core school leadership tasks, which will span the function areas of both leader strands.

8.2.1.2 School Complexity Leadership Tasks

As aforementioned, conceptualizations of schools depict them as complex adaptive systems comprising a wide range of interrelating agents affecting the overall performance of the school on two main institutional layers, namely (a) the micro-layer which focuses primarily on the teaching, learning and assessment processes and (b) the meso-layer which focuses primarily on the organizational management and development of the school (Zhao and Frank 2003; Kyriakides et al. 2010; Solar et al. 2013; Sergis and Sampson 2014). The complexity leadership approach requires school leaders to engage in a diverse set of tasks, which aim to monitor and orchestrate the full spectrum of behaviors and interactions of these agents by collecting relevant feedback loops from institution-wide eduactional data (to be defined in Sect. 2.2), and effectively exploiting them in a holistic manner.

In order to define such school leadership tasks, and formulate a School Leadership Tasks framework (SLT), a review of scientific literature and widely accepted school leader standards from major global organizations was performed (see Table 8.1). This review focused on both strands of the adopted school leader concept. However, as stated before, such role distributions are not always strictly defined within schools and the tasks descriptions per leader strand are becoming increasingly blurred (Firestone and Martinez 2009).

The review process highlighted a list of core school leadership tasks, which was post-processed toward grouping the semantically similar ones.). This process resulted in a set of commonly referenced core school leader tasks, depicted in Table 8.1. More specifically, a set of 12 commonly referenced core leadership tasks were indentified. However, "T12. Formulate Vision and Culture for Organizational Development" was not ultimately considered as a standalone leadership task in the present book chapter, since it is considered as an overarching task which affects and informs all the rest (Maslowski 2006).

Table 8.1 Core school (Complexity) leadership tasks

ID	Core school leadership task	Principal leader								Teacher leader/no distinction						
		Portin (2005)	Breiter and Light (2006)	Augustine et al. (2009)	Gill et al. (2014)	AITSL (2014)	BCP VPA (2013)	Earley (2012)	ISTE (2009)	Gill et al. (2014)	OECD (2008)	OECD (2014b)	Breiter and Light (2006)	CCSSO (2014)	TLEC (2010)	NEA (2014)
T1	Learning process monitoring	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
T2	Learning process evaluation	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
T3	Learner performance monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
T4	Learner performance evaluation		✓		✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
T5	Curriculum planning	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
T6	Teaching staff management (and hiring)	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓		
T7	Teaching staff professional development	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
T8	District stakeholder accountability	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓

(continued)

Table 8.1 (continued)

ID	Core school leadership task	Principal leader								Teacher leader/no distinction						
		Portin (2005)	Breiter and Light (2006)	Augustine et al. (2009)	Gill et al. (2014)	AITSL (2014)	BCP VPA (2013)	Earley (2012)	ISTE (2009)	Gill et al. (2014)	OECD (2008)	OECD (2014b)	Breiter and Light (2006)	CCSSO (2014)	TLEC (2010)	NEA (2014)
T9	Infrastructural resource management	✓	✓	✓		✓	✓		✓		✓			✓	✓	
T10	Financial resource management		✓	✓	✓	✓	✓		✓	✓	✓			✓		
T11	Learner data management	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓		✓
T12	Formulate vision and culture for organizational development			✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓

The remaining 11 core leadership tasks, which were utilized in this book chapter toward the formulation of the benchmarking SLT framework, are briefly outlined as follows:

- **Learning process monitoring (T1)**. This task relates to the monitoring of the learning processes that occur at the micro-layer. Data types related to this leadership task can include (a) types of instructional practices and processes utilized and (b) (quantity and) method of utilized learning resources and tools.
- **Learning process evaluation (T2)**. This task relates to the utilization of the data from the “Learning process monitoring (T1)” and their analysis toward remedying actions for improvement of the teaching and learning processes of the school. For example, this can include an evaluation of the efficiency of the adopted instructional practices (and/or learning resources and tools) using the learners’ academic performance, feedback and level of participation/engagement as a benchmark. A low level of the latter can assist school leaders to identify specific aspects of the teaching practice which were ineffective.
- **Learner performance monitoring (T3)**. This task relates to the disaggregated (for the micro-layer), as well as aggregated (for the meso-layer) data related to the learners’ academic performance. These data can include among others, behavioral issues of the learners, absenteeism rates, level of participation within the learning activities and level/type of interactions with the teacher.
- **Learner performance evaluation (T4)**. This task mainly relates to the assessment of the learners’ academic performance based on the data collected from monitoring their progress and actions during the learning process (both within and beyond the physical premises of the school). This evaluation could be diagnostic, formative, and/or summative and generate corresponding feedback loops.
- **Curriculum planning (T5)**. This task relates to the identification of issues related to the existing curriculum and the actions toward remedy. These issues are mainly elicited from the feedback loops of the previous tasks and can relate either to shortcomings identified at a micro-level (e.g., general difficulty of learners to cope with a specific curriculum section) or to externally imposed mandates (e.g., new subject domain standards).
- **Teaching staff management (T6)**. This task relates to the monitoring and management of the teaching staff of the school in terms of both teaching performance (e.g., through the monitoring of the teaching processes and the related competences of the teachers) as well as operations (e.g., attendance, demographics, and payroll).
- **Teaching staff professional development (T7)**. This task relates to the identification of potential shortcomings in the teaching staff’s competences and the organization and promotion of appropriate professional development opportunities to alleviate. Moreover, it can refer to the tasks of selecting and recruiting of new teaching staff, more appropriate for the school System needs.

- **District stakeholder accountability (T8)**. This task relates to formulating and sustaining communication channels with interested stakeholders of the school in order to allow for capturing their own feedback loops towards capturing the level in which they affect the school system's level of emergence. Examples of such two-way feedback loops can include retention rate reports and financial reports of the school addressed at the policy makers, policy mandates from the policy makers to the school, as well as continuous two-way communication and collaboration between the teachers, students and the parents of the latter.
- **Infrastructural resource management (T9)**. This task relates to the management (e.g., monitor, maintenance, procurement) of the infrastructural assets of the school, such as hardware and software equipment.
- **Financial resource management (T10)**. This task relates to the monitoring and orchestration of the financial aspects of the school, such as budget formulation, accounting tasks, and external funding.
- **Learner data management (T11)**. This task relates to the overall management of learners' data, such as demographics, tuition fees and prior academic background. Apart from the strictly administrative need for record keeping, such data types (which, like staff management, are related to the characteristics of a set of school agents) can be exploited as a means to explain the interactions of these agents with the rest of the system. Therefore, this information can facilitate in the (at least partial) understanding of the current level of system emergence.

Within the context of complexity leadership, the proposed SLT attempts to capture the core aspects of school functions which are affected by administrative leadership, but also nurture the emergent adaptive leadership. More specifically, the formulated SLT Framework describes commonly recognized aspects of school function that are orchestrated by the school leadership team and include a wider range of school System agents (e.g., parents, external accountability bodies and the students). The identified school leadership tasks are mainly related to capturing and monitoring these aspects by receiving constant flows of feedback loops from institution-wide educational data. Therefore, mechanisms for effective collection, analysis and exploitation of institution-wide data are required, towards generating evidence-based and highly granulated feedback loops. This data-driven decision making process is described in the following section in terms of (a) conceptual underpinning and (b) data type requirements in the context of school complexity leadership.

8.2.2 School Leadership Data Driven Decision Making

Data-driven decision making (DDDM) in the educational sector (and schools, in particular for the scope of this book chapter) is a practice that has gained an increasing level of attention, toward more effective leadership and organizational learning. The reason for this trend is that DDDM, apart from a well-established

Table 8.2 Definitions of school data-driven decision making

#	Source	Definition
1	Dahlkemper (2002)	DDDM is the process of collecting, analyzing, reporting, and using data for school improvement
2	Doyle (2003)	DDDM is the process of collecting student data –academic performance, attendance, demographics, etc—in such a way that administrators, teachers and parents, can accurately assess student learning
3	Crawford et al. (2008)	DDDM relates to policies and practices involving the use of student achievement and other data (such as attendance, course taking patterns and grades, and demographic data) to drive school improvement at the school, district, and state levels
4	Mandinach (2012)	DDDM is the systematic collection, analysis, examination, and interpretation of data to inform practice and policy in educational settings
5	Dunn et al. (2013)	DDDM refers to the systematic collection of many forms of data from a multitude of sources in order to enhance student performance
6	Marsh and Farrell (2014)	DDDM refers to teachers, principals, and administrators systematically collecting and analyzing various types of data […] to guide a range of decisions to help improve the success of students and schools

means for external regulatory accountability, is also identified as a driver of internal school improvement processes (Mourshed et al. 2010; Mandinach 2012; Dunn et al. 2013). More specifically, at the micro-layer, DDDM has been attributed (among others) with enhancing of student performance, mainly due to the fact that it allows for identifying potential shortcomings in the student's progress (e.g., low engagement and achievement rates) and adapting teaching strategies accordingly (Carlson et al. 2011; Hargreaves et al. 2015). At a meso-layer, DDDM is mainly utilized as a means for orchestrating strategic planning tasks, such as orchestration of staff development and recruitment (Young 2009), finances and infrastructure (Marsh et al. 2006; Schildkamp et al. 2014). Apart from the aforementioned aspects, however, DDDM is directly related to the mechanisms for capturing and exploiting feedback loops from the multi-layer educational data (i.e., characteristics and interactions of the school system agents) towards attempting to increase the transparency of the processes that formulate each status of the school system emergence.

Toward outlining the concept of DDDM, Table 8.2 presents an overview of common definitions. As the Table 8.2 depicts, all definitions (despite their diversity in the adopted level of detail) share a common core notion, namely that DDDM refers to the collection, analysis, and interpretation of institution-wide data toward generating feedback loops and insights for informing leadership in educational settings (Mandinach 2012). Therefore, data from the micro-layer should be harvested and processed in order to unravel the classroom "black box," and data from the meso-layer should be analyzed and utilized in order to inform the organizational development of the school and its strategic planning. This cyclical process comprises an initial stage of data collection, followed by the stage of analytical process and transformation of these data toward the formulation of feedback loops and the resulting stage of the provision of actionable insights (Mandinach 2012).

As aforementioned, the data harvested during the DDDM process should originate from both the micro- and the meso-layers of the institution and reflect a wide range of the schools' factors and practices. This will allow school leaders to gain insights from a holistic perspective and, thus, enable them to make more informed decisions (Earl and Katz 2006). However, given the evident diversity of these data types and sources, an efficient way should be adopted to classify and organize them toward the formulation of a School Leadership Task framework (SLT) as discussed in Sect. 2.1.

A widely accepted data type classification framework defines three main data categories, as follows (Stufflebeam and Shinkfield 2007; Ikemoto and Marsh 2007; Schildkamp et al. 2014):

- **Input data**. This category generally includes data related to learner demographics and learners' prior academic records.
- **Process/Context data**. This category refers to data related to the types and use of learning resources, teaching staff performance and competence monitoring, as well as instruction process monitoring (e.g., teaching methods utilized level of interaction with students, student level of participation). Moreover, this category can also include data from other agents of the school system, such as the parents, official policy and other schools.
- **Outcome data**. This category mainly refers to data on learner academic achievement (e.g., assessment results, level of engagement and participation, absenteeism) and retention data.

Following the above-mentioned classification framework, a set of commonly utilized data types in school leadership DDDM processes was identified and is presented in Table 8.3 (Marsh et al. 2006; Breiter and Light 2006; Picciano 2009; Copland et al. 2009; Means et al. 2010; Schildkamp and Ehren 2013; Lai and Schildkamp 2013; Murray 2013; Kaufman et al. 2014; Gill et al. 2014; Schildkamp et al. 2014).

As the Table 8.3 depicts, the set of commonly identified institution-wide data required for DDDM processes spans both micro- and meso-institutional layers and is significantly diverse and complex in order to offer effective decision support for school leaders. By combining and mapping the identified institution-wide data types that inform school leadership DDDM (Table 8.3) to the set of the eleven core school leadership tasks (Table 8.1), a school leadership task framework (SLT) is formulated and presented in Table 8.4. It essentially describes the core school leadership tasks and the specific institution-wide data types which support each of them. The SLT will be utilized for critically reviewing a set of existing school leadership decision support systems (Sect. 8.3).

However, such level of granulated data is usually difficult to attain (especially at a micro-layer) and is also delivered with significant time delay, thus impeding the

Table 8.3 Commonly utilized data types for school leadership data-driven decision making

#	Data category	Data type	Indicative example	Institutional layer
1	Input data	Learner demographics	Demographics reports	Meso
2		Learner prior academic performance	Prior academic performance records	Meso
3	Process/context data	Learner attendance	Attendance reports	Micro/Meso
4		Learner behavior	Behavior history report	Micro/Meso
5		Use of learning resources	Type of educational resources utilized	Micro
6		Learning process monitoring data	Teaching method utilized	Micro
7		School financial data	School budget	Meso
8		School infrastructural data	School (hard)/(soft) ware inventory	Meso
9		Teaching staff monitoring	Attendance, payroll, competences	Meso
10		Stakeholder evaluation data	Parent feedback	Meso
11	Outcome data	Learner assessment results	Disaggregated/aggregated learner assessment results	Meso
12		Learner retention rates	Graduation reports	Meso

capacity of leaders to identify issues to be tackled and act on-the-fly (Marsh et al. 2006; Ikemoto and Marsh 2007). Moreover, data are not informative on their own but require processing and analysis in order to make sense of them and utilize them for supporting the corresponding leadership task (Marsh et al.2006; Coburn and Turner 2011). Under the light of the above, the capacity of school leaders to perform their required tasks effectively and efficiently is directly linked to the level of availability and quality of the institution-wide data and their meaningful analysis (Mandinach 2012). In addition to this, school leaders have been reported with competence-related difficulties in analyzing the available institution-wide data and exploiting them toward delineation of actionable insights (Lai and Hsiao 2014; Marsh and Farrell 2014).

In order to address the above-mentioned issues that tend to impede the holistic data-driven leadership of schools, decision support systems have been implemented, that harvest and analyze the available data, toward the generation of feedback loops and actionable insights (Power 2008a; Kaufman et al. 2014). More specifically, decision support systems (in general, and in the context of school leadership) can afford, among others, timely harvesting and processing of data

Table 8.4 School leadership task Framework

ID	Core school leadership task	Data types
T1	Learning process monitoring	• Use of learning resources • Learning process monitoring data
T2	Learning process evaluation	• Use of learning resources • Learning process monitoring data • Learner assessment results
T3	Learner performance monitoring	• Learner attendance • Learner behavior
T4	Learner performance evaluation	• Learner assessment results • Learner attendance • Learner behavior
T5	Curriculum planning	• Learning process monitoring data • Learner assessment results
T6	Teaching staff management	• Learner assessment results • Learning process monitoring data • School staff monitoring
T7	Teaching staff professional development	
T8	District stakeholder accountability	• Stakeholder evaluation data • Learner assessment results • Learner retention rates
T9	Infrastructural resource management	• School infrastructural data
T10	Financial resource management	• School financial data
T11	Learner data management	• Learner demographics • Learner prior academic performance • Learner attendance • Learner behavior

toward effective action-taking (Pick 2008), user-friendly and elaborate visualizations toward clear sense-making (Mottus et al. 2015) and data aggregation mechanisms to address multicriteria problems (Breiter and Light 2006; Olson 2008). Despite their promise, however, decision support systems, and more specifically school leadership decision support systems (SL-DSS), have not yet reached their full potential to robustly support all tasks required for holistic school DDDM (Kaufman et al. 2014).

Under the light of the above, the contribution of this book chapter is a first step in alleviating this issue, by designing and conducting a critical analysis of 70 existing SL-DSS. More specifically, considering that SL-DSS aim to facilitate school leaders in engaging with their tasks, the issue of critically analyzing SL-DSS can be summarized as assessing the level of accommodation that the SL-DSS affordances offer in terms of the identified school leader tasks, described in the SLT. Therefore, this critical analysis of the landscape of SL-DSS could highlight potential shortcomings in terms of the affordances of these systems to adequately accommodate each school leadership task. The insights gained from this process could lead to recommendations for designing future SL-DSS, which will provide more holistic support to school leaders. The following section presents the critical analysis methodology and results.

8.3 Critical Analysis of School Leadership Decision Support Systems

8.3.1 Critical Analysis Methodology

A technical affordances-focused approach was selected for driving the critical analysis process, i.e., the selected SL-DSS were assessed solely on the premises of their functionalities' capacity to accommodate the benchmarking SLT framework (Power 2008b; Rhee and Rao 2008). Other assessment methods, such as subjective measures (e.g., user satisfaction or perceived efficiency of the decision support system) were not considered in this process.

Regarding the selection criteria utilized for formulating the list of SL-DSS to be analyzed, a threefold set was utilized, namely (a) the SL-DSS should be an standalone, already deployed system, i.e., not simply a design or an add-on to existing systems (therefore mainly commercial SL-DSS were identified), (b) the SL-DSS should be addressed at the K-12 school context, and (c) the SL-DSS should incorporate mechanisms for *actively* supporting leadership tasks (i.e., not simply harvest institution-wide data, but also utilize them toward the provision of feedback loops and actionable insights). Adhering to these three selection criteria, a set of 70 existing SL-DSS were identified via web search using the Google search engine (see Appendix for full list).

Finally, regarding the procedure of the critical analysis (i.e., the steps taken for assessing each SL-DSS), it comprised assessing each SL-DSS in terms of the cardinality of core leadership tasks (i.e., elements of the SLT) it afforded support for. Moreover, the institution-wide data types it harvested and exploited was also taken into consideration as a means of "validation," i.e., to verify that the stated core leadership task which was mentioned by the system as being supported, was indeed supported. Ultimately, the aggregated insights gained from this process could outline recommendations for the design and deployment of future SL-DSS that will provide school leaders with more holistic support in managing the organizational learning processes of their schools.

The results of the critical analysis are presented in the following subsection.

8.3.2 Critical Analysis Results

Table 8.5 presents the critical analysis of 70 existing SL-DSS, based on the SLT framework..

Figure 8.1 presents the consolidated critical analysis results on the level of accommodation that each leadership task is receiving from existing SL-DDS.

Table 8.5 Critical analysis of existing school leadership decision support systems

ID	School leadership task	School leadership decision support system ID[a]
T1	Learning process monitoring	[1], [2], [3], [4], [5], [6], [7], [9], [10], [11], [12], [13], [14], [21], [22], [23], [24], [25], [28], [29], [32], [35], [36], [39], [43], [44], [45], [49], [50], [51], [52], [53], [57], [60], [61], [64], [65], [67], [69], [70]
T2	Learning process evaluation	[3], [4], [7], [9], [10], [11], [12], [13], [14], [21], [22], [23], [24], [28], [29], [32], [43], [44], [45], [47], [49], [51], [52], [53], [57], [60], [61], [64], [65], [67]
T3	Learner performance monitoring	[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [42], [43], [44], [45], [46], [47], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [69], [70]
T4	Learner performance Evaluation	[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [12], [13], [14], [16], [17], [19], [21], [22], [23], [24], [25], [26], [27], [28], [29], [32], [34], [35], [36], [37], [39], [43], [44], [45], [46], [47], [49], [50], [51], [52], [53], [54], [55], [57], [58], [59], [60], [61], [62], [63], [64], [65], [67], [69], [70]
T5	Curriculum planning	[3], [4], [7], [9], [11], [12], [13], [14], [21], [22], [23], [24], [28], [29], [32], [37], [43], [44], [45], [47], [49], [51], [52], [53], [57], [60], [61], [63], [64], [65], [67], [69], [70]
T6	Teaching staff management	[2], [3], [5], [6], [7], [9], [11], [12], [13], [15], [17], [18], [20], [22], [24], [28], [29], [32], [33], [34], [36], [37], [38], [40], [43], [44], [45], [46], [47], [48], [49], [51], [52], [53], [54], [55], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69]
T7	Teaching staff professional development	[2], [7], [9], [11], [12], [13], [17], [18], [20], [21], [23], [24], [28], [29], [32], [34], [36], [37], [40], [44], [47], [48], [49], [51], [52], [53], [54], [57], [64], [68], [69]
T8	District stakeholder accountability	[1], [2], [3], [4], [5], [6], [7], [9], [10], [11], [13], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [42], [43], [44], [45], [46], [47], [49], [50], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [63], [64], [65], [66], [67], [69]
T9	Infrastructural resource management	[2], [9], [18], [22], [33], [36], [38], [41], [45], [46], [48], [49], [52], [55], [57], [58], [61], [62]
T10	Financial resource management	[2], [3], [4], [7], [9], [12], [13], [18], [20], [22], [26], [31], [33], [34], [36], [41], [44], [45], [46], [48], [49], [52], [62], [66], [69], [70]
T11	Learner data management	[1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [12], [13], [15], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [42], [43], [44], [46], [47], [48], [49], [50], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [69], [70]

[a]The “School leadership decision support system ID” is defined in the Appendix

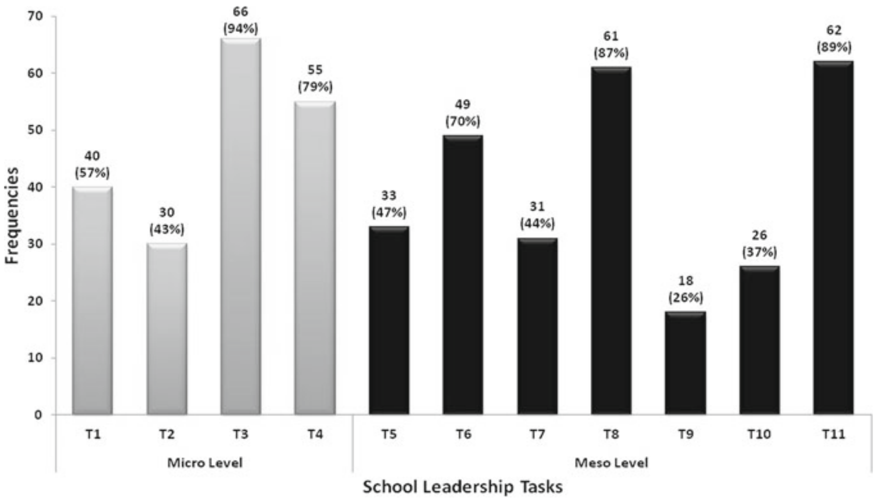

Fig. 8.1 Frequencies of SL-DSS supporting each school leadership task

As the Fig. 8.1 depicts, the consolidated overview of the existing SL-DSS highlights a set of key findings, which are described as follows:

- The leadership tasks receiving the highest level of accommodation are "*T3. Learner Performance Monitoring*" (N = 66, x = 94 %), "*T4. Learner Performance Evaluation*" (N = 55, x = 79 %), "*T8. District Stakeholder Accountability*" (N = 61, x = 87 %) and "*T11. Learner Data Management*" (N = 62, x = 89 %). This finding mirrors the common notion that school leadership is heavily influenced and driven from the external regulatory accountability man dates, either officially from policymakers or unofficially from parents and other schools. Under this light, SL-DSS have placed a significant level of attention in assisting leaders to effectively capture, monitor, and enhance learner performance (mainly through assessment results and attendance rates) to meet these accountability goals. The majority of existing SL-DSS also aim to facilitate leaders in reporting these learner performance data to the interested stakeholders, by providing aggregation and report formulation functionalities.
- The leadership tasks receiving the lowest level of accommodation are "*T9. Infrastructural Resource Management*" (N = 18, x = 26 %) and "*T10. Financial Resource Management*" (N = 26, x = 37 %). These types of meso-layer tasks, therefore, appear to be undersupported (from an aggregated view) from SL-DSS and, therefore, their interrelation with other institution-wide data toward holistic decision support is not widely provided. However, this can prove to be an important shortcoming, since the quality, availability, and quantity of both school infrastructure (e.g., OECD 2011) as well as school financial resources (e.g., Nachmias et al. 2004) can greatly affect the teaching and learning

processes of the micro-layer. Therefore, more attention should be provided to support these leadership tasks, in order to facilitate more holistic school management.

- The meso-layer leadership tasks "*T6. Teaching Staff Management*" ($N = 49$, $x = 70\ \%$) and "*T7. Teaching Staff Professional Development*" ($N = 31$, $x = 44\ \%$) appear to be considered as important by a significant portion of the SL-DSS (especially task T6), which provide decision support affordances for supporting them. More specifically, the majority of the teaching staff management affordances refer to teaching staff demographics, attendance, payroll, as well as recruitment facilitation. The teaching staff professional development affordances are generally related to the cultivation of professional learning communities and (in cases of formal professional development), tracking of the progress of the teachers toward completion. Future SL-DSS could focus more on the aspect of promoting targeted teacher professional development, considering data collected from the micro-layer and the insights these could yield concerning the competences of the teacher. The latter could be measured through official teacher competence frameworks [such as the UNESCO ICT Competency Framework for teachers (UNESCO 2011) or Technological Pedagogical Content Knowledge (TPACK, Koehler and Mishra 2009)], and be mapped to professional development courses which will cultivate the specific competences that each teacher is lacking (Sergis et al. 2014a, b).
- Finally, the micro-layer leadership tasks "*T1. Learning Process Monitoring*" ($N = 40$, $x = 57\ \%$) and "*T2. Learning process Evaluation*" ($N = 30$, $x = 43\ \%$), have received a moderate level of accommodation. The latter poses an interesting finding, since these tasks are required for facilitating teacher's reflection and development toward enhancing learners' performance (OECD 2009; Vieluf et al. 2013). This fact is also mirrored in the low level of accommodation that the leadership task "*T5. Curriculum Planning*" is receiving ($N = 33$, $x = 47\ \%$). More specifically, data collected in T1 and T2 (including types of learning resources utilized, the level of their usage, and the type/diversity of instructional methods and practices employed by the teacher) can provide a wealth of information for the targeted identification of the roots for issues underlying other leadership tasks (i.e., T3, T4, T5, T7 and T11). Therefore, this limited accommodation from SL-DSS is deemed as significant and supports the finding that existing SL-DSS seem to place much attention in monitoring learners' performance and retention from a clear external regulatory accountability perspective.

In the light of the last finding, an additional level of qualitative meta-analysis was performed for "*T1. Learning Process Monitoring,*" toward gaining a more detailed insight of the exact level of accommodation that each data types that feed this task are receiving (based on the analysis of Sect. 2.2). The meta-analysis process highlighted that the data type "*T1a. Types and level of usage of learning resources utilized*" is universally accommodated by the portion of SL-DSS which support the leadership task T1. On the other hand, a surprisingly low portion of 13 SL-DSS ($x = 32\ \%$ of the SL-DSS portion supporting task T1, and $x = 19\ \%$ of the overall 70 SL-DSS) harvest data related to the actual methods and practices that the teachers utilize in their classrooms, i.e., data type "*T1b. Instructional methods and practices employed.*" Despite the widely accepted notion that teaching methods directly influence the level of learners' outcomes (as well as level of engagement, motivation, etc.), the majority of existing SL-DSS does not harvest sufficient data to inform school leadership toward remedying for potential shortcomings in terms of the teaching practices being employed in the micro-layer. Moreover, the performed analysis indicated that even the small portion of them that do harvest such data ($x = 19$ % of the overall 70 SL-DSS), do not link them to the other institution-wide data collected (such as learner performance, learner retention rates, and teacher competences) toward holistic assessment of the teaching practices and leader reflection.

The above-mentioned situation highlights that making transparent the "black box" of the classroom is apparently not yet widely achieved and targeted at. Moreover, this supports the notion that the main scope of external regulatory accountability is still (to a large extend) focused at monitoring the quantitative data of learners' assessment results and retention rates, rather than the quality and appropriateness of the teaching practices that take place in the classrooms (Knapp and Feldman 2012; Gonzalez and Firestone 2013). However, it is the latter which holds the greatest promise toward school improvement since it can directly influence (and be influenced by) all other leadership tasks from learner performance and teacher professional development to management and procurement of required infrastructural assets (Cranston 2013). Therefore, the very limited level of accommodation from existing SL-DSS on these data types (and corresponding core leadership tasks) is considered to be an important shortcoming. Additionally, given the emerging trend of external accountability beyond mere quantitative assessment measures toward qualitative performance-based evaluations of schools, supporting school leaders in effectively capturing and monitoring the teaching processes of their school will likely become a major requirement for future SL-DSS (Altrichter and Kemethofer 2015).

Finally, besides external accountability (to both policymakers and parents) these micro-layer data can be of great value in terms of providing evidence to the overall teaching community to support (or oppose) best practices of teaching in particular contexts. More specifically, utilizing the currently harvested wealth of other institution-wide data types (e.g., learner demographics and school infrastructure), future SL-DSS could formulate a detailed learning contextual framework (i.e., the learning environment), in which different teaching approaches could be tested and reflected upon, using the learner outcomes as a benchmarking means. By doing that, evidence on the best practices could be gathered, since both the "black box" of the classroom as well as the context of the school in which the teaching practice is being performed, would be linked to the teaching process and the resulting learner outcomes. Therefore, each teaching practice could be evaluated based on not only the static description of its components (e.g., educational objectives, learning activities, educational resources, and tools), but also based on a highly granulated representation of (a) the context in which the practice was executed and (b) the outcomes it delivered on the learners. Afterwards, these pools of teaching practices (with all their aforementioned detailed meta-information) could be shared through web-based repositories, in which school teachers could identify the "best teaching practices" for their needs, based on their own institution's and classroom's contextual information.

8.4 Conclusions

The global push toward school autonomy and accountability has assigned school leaders with a diverse and complex set of tasks toward meeting organizational goals, as well as delivering high levels of quality in terms of actual learning outcomes for their students. Engaging with these tasks requires harvesting and processing a diverse set of institution-wide data. To effectively address this issue, school leadership decision support systems are deployed. This book chapter presented a critical analysis of a set of 70 SL-DSS, benchmarked against core leadership tasks which they aim to support, in an attempt to identify shortcomings and to pinpoint potential areas of future development.

The results of the critical analysis highlighted that the vast majority of identified SL-DSS specifically focused on assisting school leaders cope with the externally mandated regulatory accountability requirements in terms of monitoring, enhancing and reporting students' summative assessment score data and/or retention rates. On the other hand, meso-layer "business" managerial tasks such as the management and strategic orchestration of the schools' finances and infrastructure have received much less attention, thus hindering the capacity of leaders to include such information in their holistic planning.

Additionally, a significant shortcoming of existing SL-DSS relates to the very limited quantitative and qualitative accommodation of micro-layer data that could inform meaningful internal school improvement (as well as qualitative performance-based external accountability), such as a detailed monitoring and reflective evaluation of the teaching practices employed by the teachers are not yet widely harvested and processed. Specific focus should be placed on this aspect, however, based on both the emerging trends of qualitative external accountability, which will most likely require such data to be harvested and presented in the future, as well as the significant added value it can offer in terms of promoting the teaching profession and formulating pools of teaching practices (e.g., educational scenarios or lesson plans) which will not only present the "static design" of this practice, but will also attach to it the specific contextual parameters in which the practice was performed and the learner outcomes it produced within this specific context of execution.

In conclusion, future SL-DSS should attempt to deliver concrete solutions to the aforementioned shortcomings toward providing school leaders with powerful tools that will not only scan the current status of their school from a "quantitative" approach, but will also generate "qualitative" insights and solutions based on concrete evidence and institution-wide data processing.

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Appendix

In Table 8.6, the detailed list of the school leadership decision support systems identified and utilized in the book chapter is presented, i.e., their title and URL.

Table 8.6 List of school-oriented leadership decision support systems (SL-DSS) reviewed in Sect. 8.3

ID	SL-DSS	URL	ID	SL-DSS	URL
[1]	Fresh grade	https://www.freshgrade.com	[36]	Tyler tech	http://tinyurl.com/mnwwrqk
[2]	LongLeaf	http://www.longleafsolutions.com	[37]	EdPlan	http://tinyurl.com/mvk3el7
[3]	Edumate	http://www.edumate.com.au	[38]	IRIS	http://tinyurl.com/ljgfb9r
[4]	Jupiter Ed	http://jupitered.com	[39]	Learnsmart	http://tinyurl.com/nqxddsf
[5]	Ellevation	http://ellevationeducation.com	[40]	TalentEd	http://www.netchemia.com
[6]	Schoolzilla	https://schoolzilla.org	[41]	SchoolDude	www.schooldude.com
[7]	Brightbytes	http://brightbytes.net	[42]	Attention2Attendance	http://tinyurl.com/mzpxsfa
[8]	Learnsprout	http://www.learnsprout.com	[43]	Performance matters	http://tinyurl.com/m5m4kwd
[9]	Powerschool	http://tinyurl.com/mh57pll	[44]	Circulus education	http://tinyurl.com/k7g9kc2
[10]	Canvas	http://www.instructure.com	[45]	K12 systems	https://www.k12system.com
[11]	Brightspace	http://www.brightspace.com	[46]	Schoolutions	http://tinyurl.com/kgdv8xu
[12]	SunGuard	http://sungardk12.com	[47]	Software nology	http://softwarenology.com
[13]	BlackBoard analytics	http://tinyurl.com/mglvcdt	[48]	K12 enterprise	http://www.k12enterprise.com

(continued)

Table 8.6 (continued)

ID	SL-DSS	URL	ID	SL-DSS	URL
[14]	Schoology	http://www.schoology.com	[49]	File maker	http://tinyurl.com/mrynqwj
[15]	Tableau	http://tinyurl.com/pnercuj	[50]	eStar	https://www.esped.com
[16]	Edusight	www.edusight.co	[51]	Corner stone	http://tinyurl.com/k2lmzdm
[17]	Grade analyzer	http://www.gradealyzer.com	[52]	IBM education	http://tinyurl.com/pw5vrbj
[18]	Dell ED management	http://tinyurl.com/k9bufwy	[53]	Mastery connect	http://www.masteryconnect.com
[19]	Bulker systems	http://tinyurl.com/p2ljfu6	[54]	Scantron analytics	http://www.scantron.com
[20]	K12 dynamics	http://k12dynamics.com/dashboard	[55]	Data house	http://tinyurl.com/mkcvo45
[21]	Its learning	http://www.itslearning.net	[56]	Kinvolved	http://kinvolved.com
[22]	Skyward	http://www.skyward.com	[57]	Paragon K12	http://tinyurl.com/nsmclcw
[23]	Focal point K12	http://www.focalpointk12.com	[58]	SAS K12	http://tinyurl.com/ne9zvwn
[24]	Dreambox	http://www.dreambox.com	[59]	Unissant	http://tinyurl.com/ps2mzov
[25]	Streams Junyo	http://streams.junyo.com	[60]	Get alma	http://www.getalma.com
[26]	Phytorion	http://tinyurl.com/psza4p8	[61]	Open SIS	http://tinyurl.com/lkms2n2
[27]	P3 strategies	http://tinyurl.com/lh2x482	[62]	DataBlocs K-12 solutions	http://www.datablocs.com
[28]	Stars	http://www.schoolcity.com	[63]	Accelify	http://www.accelify.com
[29]	Learning qube	http://tinyurl.com/o9jnnd7	[64]	KickBoard	http://tinyurl.com/6xtlxno
[30]	Class Charts	https://www.classcharts.com	[65]	TopScholar	http://www.topscholar.co
[31]	BlackBaud	https://www.blackbaud.com/k-12	[66]	MyDistrict360	http://www.mydistrict360.com
[32]	K12 analytics	http://www.k12analytics.com	[67]	RealizeIt	http://realizeitlearning.com
[33]	Enlit	http://enlitllc.com	[68]	Teacher match	https://www.teachermatch.org
[34]	Ed analytics	http://edanalytics.org	[69]	TIES	http://ties.k12.mn.us
[35]	Illuminate education	https://www.illuminateed.com	[70]	EdMin	http://edmin.com

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Chapter 9
Educational Leadership and Planning for Digital Manufacturing in Schools

Glen Bull, Nigel Standish, Eric Johnson and Hossein Haj-Hariri

Abstract Desktop manufacturing systems such as 3D printers and computer-controlled die cutters have recently become affordable in schools. Because this technology is evolving rapidly, considerable experimentation is occurring as teachers explore opportunities to enhance learning across a range of content areas. Central coordination and planning can facilitate effective use of digital manufacturing technologies in schools. Factors that should be considered include acquisition of technology, placement, and support of the technology, safety, alignment with educational standards and learning objectives, scheduling, and professional development.

Keywords Desktop manufacturing · Digital fabrication · 3D printing · Engineering education · STEM

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9.1 Introduction

The last half of the twentieth century was marked by a transition to digital computers. This was accompanied by a conversion of physical objects into digital format. Books, movies, music, medical images, such as X-rays, and architectural and engineering drawings were all converted into digital form. This process changed many aspects of work and social life. For example, a radiologist in New Delhi can now read a digital X-ray of a patient in New York. This is also inexorably changing education as online courses become feasible.

At the same time this was occurring, the beginnings of a less remarked upon trend were also occurring. Manufacturers began to use digital processes to control production of physical goods and objects. In the 1960s, numerically controlled lathes and milling machines allowed the operator to dial in manufacturing parameters with a series of numbers. These early efforts led to the use of mainframe and mini-computers to control these manufacturing processes. These computer-numerical controlled (CNC) manufacturing machines were expensive and required specialized expertise to operate.

Today, however, digital chips that cost a dollar or two have more computational power than the mainframe computer in mission control that guided the first Apollo flight to the moon. When computers cost more than a million dollars, computer-controlled manufacturing processes were only feasible in industrial settings. The availability of inexpensive digital microcontrollers has greatly reduced the cost of digital fabrication. This has led to widespread availability of advanced manufacturing technologies that are accessible to consumers and to schools (Anderson 2012).

At the turn of the century, in 2001, Neil Gershenfeld founded the Center for Atoms and Bits at M.I.T. to advance research on digital fabrication technologies. This led to development of Fabrication Laboratories (FabLabs) and a related course, "How to Make (Nearly) Anything." The goal of this effort was to "democratize access to personal and collaborative invention using digital technologies to make 'almost anything'" (Gershenfeld 2005).

Today schools are beginning to acquire digital fabrication technologies, primarily 3D printers (Berry et al. 2010; Lipson and Kurman 2013). However, just as careful planning is required to capitalize on effective use of information technologies in schools, educational leadership will also be required to make best use of digital manufacturing technologies in schools (National Academy of Engineering 2005). The specific uses and applications will vary according to the individual needs of each school system. There are a number of parameters that can be used to guide the planning process in each school system.

9.2 Laboratory School for Advanced Manufacturing

In 1896, John Dewey established the first laboratory school, founded in a collaboration between faculties at the University of Chicago and local educators, students, and parents. It was designed to serve as a laboratory for development of effective educational practices. Since that time, approximately two dozen laboratory schools have been established across the nation.

In 2013, the Laboratory School for Advanced Manufacturing (Lab School) was established as a joint venture by the University of Virginia's Curry School of Education and School of Engineering and Applied Science in collaboration with the Charlottesville City Schools and the Albemarle County Public Schools (Bull et al. 2014b). Model facilities for integration of engineering design into the K-12 curriculum were established at Buford Middle School and Sutherland Middle School. In addition, a K-12 Engineering Design Laboratory was established to support this effort in the School of Engineering and Applied Science at the University of Virginia. The goal of the Lab School is to identify and develop effective educational practices for use of advanced manufacturing technologies in K-12 schools (Bull et al. 2015).

The Lab School was designed to explore integration of engineering design into other disciplines through use of advanced manufacturing technologies. Engineering design is a "systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" (Dym et al. 2005, 103). Engineering design is difficult to learn, teach, and assess (Katehi et al. 2009). Advanced manufacturing technologies offer student the opportunity to learn about engineering design through the experience of seeing their ideas realized in physical form (Bull and Groves 2009; Chiu et al. 2012) (Fig. 9.1).

Fig. 9.1 The laboratory school for advanced manufacturing was launched in fall 2013

Some of the practices developed through pilot work in the Lab School are described below. In particular, use of this capability to develop and support physical instructional materials in ways that would not have been possible before are reviewed.

9.3 Leadership and Planning

As 3D printers have decreased in price, many individual teachers are purchasing them for use in their classrooms. Some innovative work is emerging from the efforts of these pioneering educators (Bull et al. 2013). But just as the power of computers is amplified when they are networked in an integrated system, the potential of advanced manufacturing technologies is enhanced when coordinated choices are made by educational leaders in schools.

9.3.1 The Importance of Leadership

Leadership is a crucial element of an effective, sustainable advanced manufacturing program. Replicable advanced manufacturing programs require an infrastructure and support system that exceeds the capabilities of any single individual.

The Lab School receives several inquiries each week seeking information about use of 3D printers in schools. In addition, a number of educational leaders visit the school each year to tour the physical facilities. These have included visitors from Europe and Asia as well as the U.S. In each of these cases, visitors invariably focus on the physical equipment. Questions typically relate to ways of acquiring equipment, how to budget for it, and how to maintain it.

Physical equipment is the most tangible element of an advanced manufacturing program in a school. However, the critical elements for success are less visible. These involve elements such as scheduling and professional development. Successful integration involves many of the factors that are involved in operation of an industrial factory, such as workflow, sourcing, and acquisition of parts and materials. In addition to these logistical factors, effective use of digital manufacturing technologies also requires alignment with curricular goals and instructional standards.

Issues that a leadership and planning team will need to consider are outlined below. These choices involve the types of technologies that are acquired, the spaces in which they are placed, the way in which use of technologies is coordinated across disciplines, the manner in which professional development for teachers is provided, and factors such as scheduling and assessment.

9.3.2 Fabricating Physical Mechanisms to Support Instruction

Schools now have the capability to produce physical mechanisms to support instruction (Bull et al. 2009). Cornell University has done this with its Reuleaux Collection of mechanical engineering mechanisms. These models were used to teach engineers about underlying mechanisms of machines in the nineteenth and early twentieth century. Cornell made its collection of mechanisms available through its Kinematic Models for Design digital library (kmoddl.library.cornell.edu). This library allows others to use 3D printers to fabricate working copies of the mechanisms. Hod Lipson notes that in the past physical models were "rarely made or shared outside of an educational institute because of the costs involved in making, maintaining, and shipping models, model fragility, and other logistical constraints" (Lipson and Kurman 2013).

The Lab School engaged in a similar collaborative initiative with the Smithsonian Institution (Bull et al. 2014a). The project, American Innovations in an Age of Discovery: Teaching Science and Engineering through Historical Reconstruction, involves identification of key inventions in American history. Selected inventions such as the telegraph, the telephone, and early electric motors are digitized and made available on the Smithsonian X 3D web site (3d.si.edu/invention). Web-based tools allow students to inspect and analyze the inventions with the goal of reconstructing those using advanced manufacturing technologies (Fig. 9.2).

9.3.3 Acquisition of Technology

At present much of the attention related to digital fabrication in schools is focused on 3D printers. The function of 3D printers is easy to understand and they have steadily become more capable as they have decreased in price. By far, the greatest number of articles about advanced manufacturing technologies in the popular press focuses on 3D printers. However, there are many other digital fabrication technologies. These include computer-controlled die cutters, digital milling machines, laser cutters, and other technologies (Bull et al. 2013).

Neil Gershenfeld has commented that focusing on only 3D printers is comparable to designing a kitchen that only has a microwave oven (Gershenfeld 2005). While the microwave is a useful tool, many other culinary tools are also incorporated into a well-designed kitchen. Likewise, each fabrication tool has its own characteristics.

For example, a digital die cutter is inexpensive and can be acquired for $100. It can be used with inexpensive materials such as card stock and typically can fabricate an object in a minute or two. This makes it ideal for prototyping use in the classroom (Bull and Garofalo 2015). In contrast, most objects of any complexity

Fig. 9.2 A lab school teacher uses Smithsonian Electric Motor Invention Kits to teach electricity and magnetism

produced with a 3D printer take several hours to fabricate. This means that an object fabricated with a 3D printer typically cannot be designed and produced in the same class period. These characteristics affect the logistics of classroom planning (Table 9.1).

A reproduction of Morse's telegraph and relay can be quickly and inexpensively fabricated with a digital die cutter. This makes it feasible to allow each student to experiment with design and fabrication of a telegraph in a single class period. A 3D printer will fabricate a more durable version with plastic, although at a higher cost (Fig. 9.3).

Similarly, a version of Galileo's clock that takes 14 h to print at a cost of $100 in materials can be produced in fifteen minutes for $10 with a laser cutter. However, the initial acquisition cost of the laser cutter is much higher (Table 9.2).

Table 9.1 Selected digital fabrication tools

Fabricator	Price	Material	Speed
Digital die cutter	$100	Cardstock and vinyl	Fast
3D printer	$1000	ABS or PLA Plastic	Slow
Digital milling machine	$1000	Wood or plastic	Slow
Laser cutter	$10000	Wood or acrylic	Fast

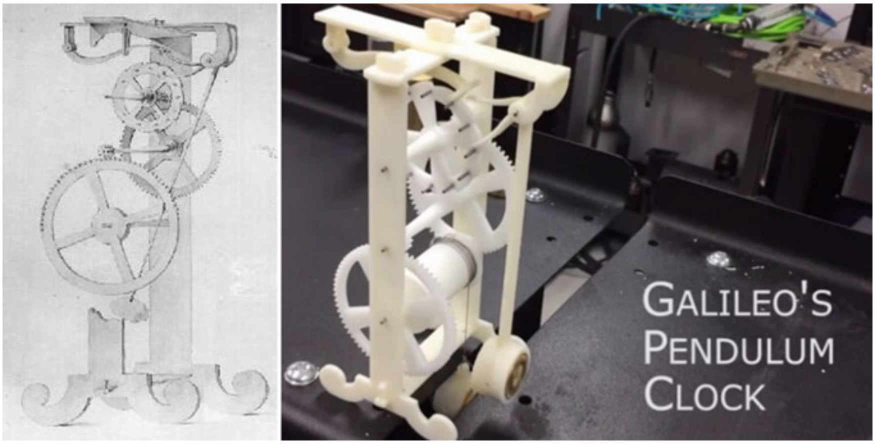


Fig. 9.3 Galileo's clock (*left*) and a modern reconstruction (*right*)

Table 9.2 Fabrication time and materials cost

Fabricator	Telegraph	Galileo's clock
Die cutter	Time = 15 min $1 in materials	
3D printer	Time = 2 h $10 in materials	Time = 14 h $100 in materials
Laser cutter		Time = 15 min $10 in materials

Table 9.3 Characteristics of digital fabrication tools

Fabrication tool	Acquisition cost	Operation cost	Speed of operation	Durability of product
Digital die cutter	Low	Low	Fast	Fragile
3D printer	Moderate	Moderate	Slow	Durable
Digital milling machine	Moderate	Moderate	Slow	Durable
Laser cutter	High	Low	Fast	Durable

The function of each digital fabrication tool can be summarized with respect to four parameters: (1) acquisition cost, (2) operation cost, (3) speed of operation, and (4) durability of product. An effective plan for a school system will incorporate an appropriate mix of these tools. Digital die cutters are particularly well suited for elementary classrooms because they are inexpensive and safe to use. This early use of digital tools serves as scaffolding to support use of more complex fabrication systems in later grades (Table 9.3).

Finally, it should be considered that in industry these tools are primarily used for rapid prototyping and design rather than manufacturing. Once a design is perfected, processes such as injection molding are used to manufacture the object quickly and inexpensively in large quantities. To provide a sense of scale, more plastic is used for processes such as injection molding in less than a minute than has been used by 3D printers since the invention of this technology (S. Wright, personal communication, December 12, 2014).

Therefore, if an item is needed in large quantities in a school (e.g., one for every member of a class), other manufacturing technologies such as resin-based casting should be considered. Both the cost and production time may be considerably less in some instances. A rapid prototyping tool such as a 3D printer can be used to fabricate a single instance of an item. This original item is used to create one or more molds. The molds created in this fashion are then used to replicate multiple copies.

9.3.4 Electronic Technologies and Control Systems

With the advent of advanced manufacturing technologies, a new discipline emerged that combines elements of mechanical engineering, electrical and electronic engineering, and control systems. The portmanteau word *Mechatronics* was formed from "mechanical engineering" and "electronics" to describe this engineering discipline. It encompasses electromechanical systems and instrumentation that are used to bring objects to life. This can include sensors and actuators, microcontrollers, and the software needed to guide their operation.

The engineering disciplines represented include (1) mechanical engineering, (2) electrical engineering, and (3) computer science. A well-designed advanced manufacturing program will include all three disciplines and the full range of technologies represented by the field of mechatronics (Table 9.4).

Table 9.4 Mechatronics encompasses three formerly disparate engineering disciplines

Engineering discipline	Technology	K-12 engineering tools
Mechanical engineering Digital fabrication	Additive fabrication	Desktop 3D printer casting and molding
	Subtractive fabrication	Digital die cutter Laser cutter Desktop CNC machine
	CAD software	Maker studio AutoCAD inventor
Electrical engineering Electromechanical systems and instrumentation	Sensors	Vernier/Pasco sensors
	Actuators	Motors and solenoids
	A/D and D/A Conversion	Arduino
Computer engineering Control systems	Control software	Scratch LabVIEW for mindstorms
	Microcontrollers	Arduino

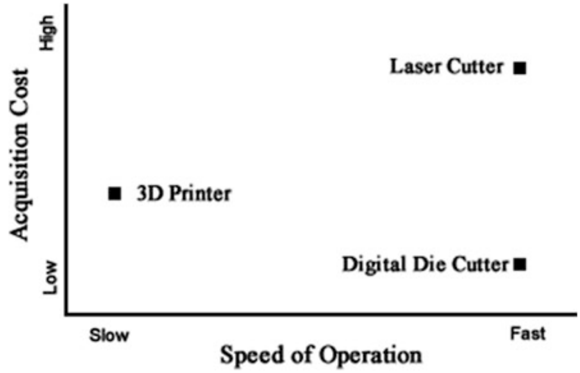


Fig. 9.4 Factors that affect placement of manufacturing technologies in schools include acquisition cost and speed of operation

9.3.5 Placement of Technologies

A key planning decision involves placement of advanced manufacturing technologies in schools. One option is to place equipment directly in the classroom. Another possibility is to place equipment in a shared central location. Placement in the classroom allows students to make use of the technologies at the times that best integrate with the lesson and instructional goals. Technologies that are relatively affordable, such as digital die cutters, can be placed directly in the classroom to allow students the experience of rapid prototyping in the context of their lessons.

Technologies that are too expensive to place in a single classroom, such as laser cutters, will need to be placed in a central location. 3D printers fall in between and therefore may be placed directly in a classroom or in a central location, depending on the circumstances (Fig. 9.4).

The Laboratory School for Advanced Manufacturing is a distributed collaborative school with three digital manufacturing sites—one in the city school system, one in the county school system, and one at the university. Each of the three sites serves as a test bed to explore different configurations. Each school and school system is different and therefore requires planning and decisions unique to that system. However, the different strategies adopted in different Lab School sites provide an initial framework for considering different options (Fig. 9.5).

In the Buford Engineering Design Academy, 6 advanced manufacturing stations were established in each science classroom—one for each of 6 science lab stations. Each station includes a digital die cutter, an inkjet printer, and a 3D printer. In a class of 24 science students, this provides one digital die cutter and one 3D printer for each team of four students. A separate engineering suite includes a Rapid Prototyping Laboratory with a laser cutter and additional 3D printers. The engineering suite also includes a Mechatronics Laboratory with electronic prototyping boards, integrated circuits, hand tools, and a Computer Assisted Design (CAD) Lab. The science classrooms are on one side of a corridor while the engineering suite is on the other side of the hallway (Fig. 9.6).

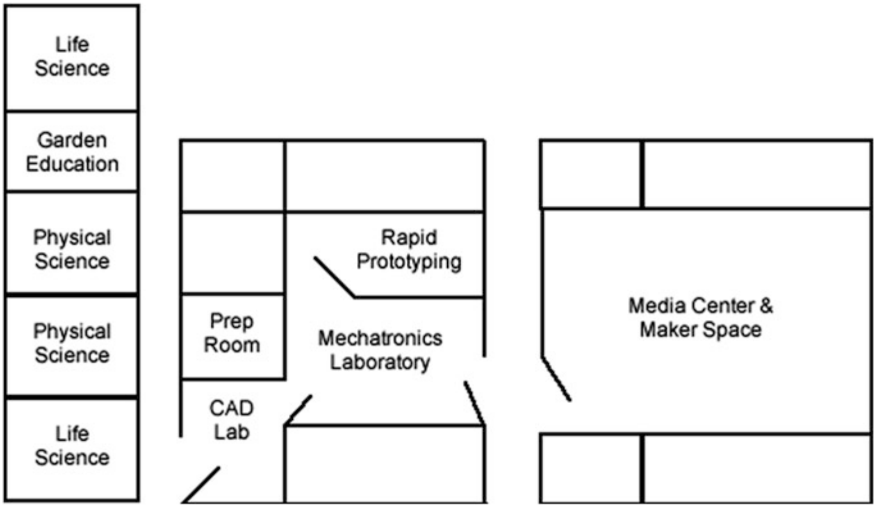
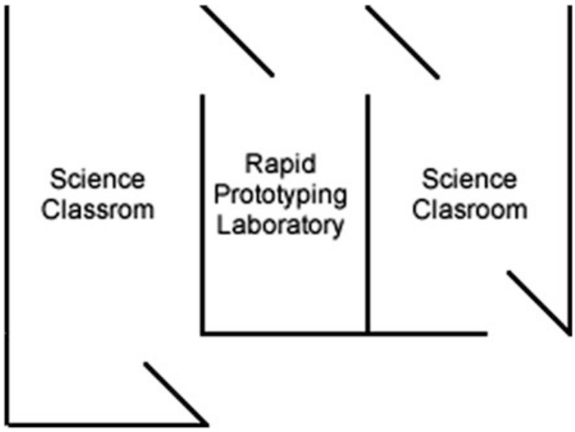


Fig. 9.5 Engineering facilities in the Buford Engineering Design Academy

Fig. 9.6 Digital fabrication facilities in the Sutherland Engineering Design Academy



In contrast, the Sutherland Engineering Design Academy incorporates a central Rapid Prototyping Lab between two of the science classrooms. The prototyping lab includes digital die cutters, inkjet printers, and 3D printers. Glass walls on each side of the prototyping lab allow students from each science class to monitor the progress of digitally fabricated objects as they are made. A separate engineering suite includes two rooms—one with a laser cutter and traditional power tools (lathe, drill press, etc.) and a second room that functions as a CAD lab.

As advanced manufacturing technologies are incorporated into schools, safety is an important architectural consideration. In 2013, the first peer-reviewed study of

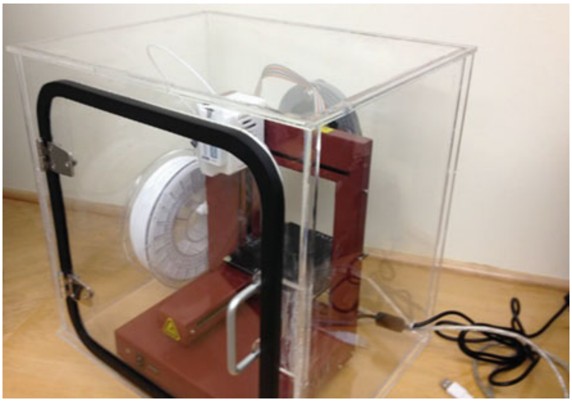


Fig. 9.7 Prototype enclosure for containment of nanoparticles

nanoparticle emissions by desktop 3D printers was published. The study, "Ultrafine Particle Emissions from Desktop 3D Printers," conducted by the Environmental Research Group at the Illinois Institute of Technology indicates that 3D printers can be characterized as "high emitters of ultrafine particles (UFPs)" (Stephens et al. 2013). This potentially could result in health hazards such as pulmonary embolisms (Fig. 9.7).

For that reason, the rapid prototyping laboratories at both Buford and Sutherland incorporate augmented ventilation systems that replace the air in each room at a rate of 4–6 times per hour. As an alternative to whole-room enclosure of 3D printers, an emission control system was also designed to enclose individual 3D printers. These enclosures can either be exhausted to the outside, or connected to an appropriate HEPA filter. In the future, these enclosures will be incorporated directly into some 3D printers, such as the Afinia Model 800D 3D printer.

9.3.6 Coordination of Technologies Across Disciplines

During America's industrial revolution, science was applied to engineering on a large scale for the first time. The result was many of the great innovations that shaped the world (i.e., telegraph, electric motors, telephone, and radio). In collaboration with the Smithsonian Institution, Lab School students are designing and fabricating working reinterpretations of key inventions in history (Bull et al. 2014a). Objects from the Smithsonian collections such as artifacts and three-dimensional models, patent descriptions, and inventors' notebooks are used in this process. The science and engineering teachers at the Lab School work collaboratively to enable the students to address these challenges and enhance both disciplines.

This approach, termed historical scaffolding, is being adapted for K-12 schools by the Lab School based on prior work in the Joseph Henry Center at Princeton (Billington and Billington 2006). (Joseph Henry, the first secretary of the

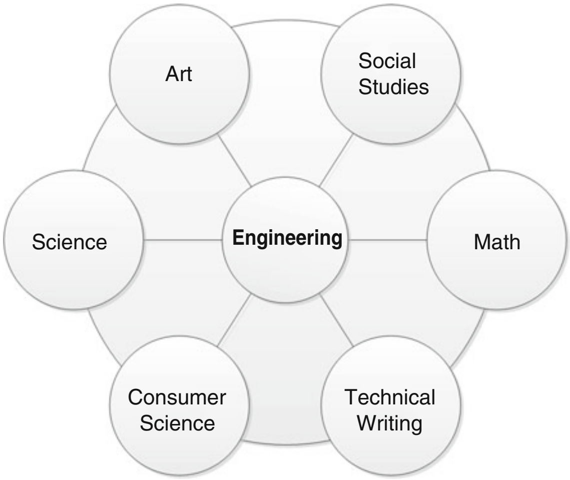


Fig. 9.8 Cross-disciplinary connections between engineering and content areas

Smithsonian, taught at Princeton.) Thus, advanced manufacturing technologies are used to foster collaboration across science, engineering, and history classes. Connections between engineering and other disciplines were established that encompass the following subjects: art, social studies, mathematics, technical writing, consumer science, and physical science (Fig. 9.8).

For example, the expertise that students acquire in engineering class is being employed to scaffold development of kinetic sculptures and interactive murals in art class. The collaborative process of invention is used to support development of effective technical writing skills. This work also provides an authentic context for applied use of mathematics.

Coordination of these efforts across disciplines requires significant attention to scheduling by principals. This is a crucial factor in the effective integration of advanced manufacturing technologies, and one of the most important and complex planning elements. Engineering electives or equivalent career and technical education (CTE) courses are the center of an advanced manufacturing hub in the lab school. These courses have proven to be popular with students. However, engineering electives compete for space in the curriculum with other electives such as art, music (band and orchestra), world languages, and sports. The school schedule must balance the needs of all of these electives to allow as many students as possible to enroll in the course of their choice.

Both Lab School sites offer physics in the spring. An electricity and magnetism unit has been developed around a reconstruction of an “Electromagnetic Engine” patented by Charles Page in 1854 (Figs. 9.9 and 9.10).

The physical science classes previously used a demonstration motor purchased from a science supply house. Due to budget constraints, each teacher only had access to a single demonstration motor. Consequently, the class was taught through lecture-style demonstration with the single demonstration motor at the front of the classroom.

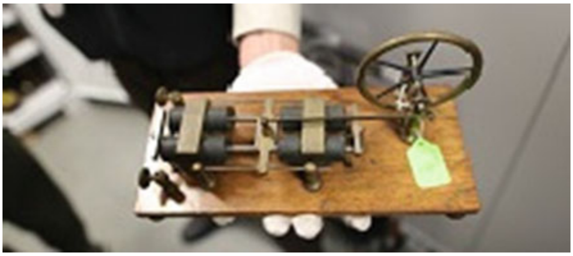


Fig. 9.9 The original Charles Page patent model in the Smithsonian collections

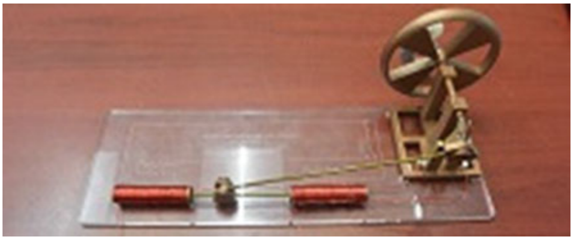


Fig. 9.10 A historical reconstruction of the Charles Page motor fabricated with advanced manufacturing technologies

With the advent of advanced manufacturing technologies, these resources are redirected to create a modern-day reconstruction of the Charles Page engine in an elective engineering class. The reconstructed motors fabricated in engineering class are then used as the basis of the electricity and magnetism unit in physics class (Fig. 9.11).

Use of an electric motor kit fabricated by a member of the science team who is also enrolled in an engineering elective offers several advantages. First, one

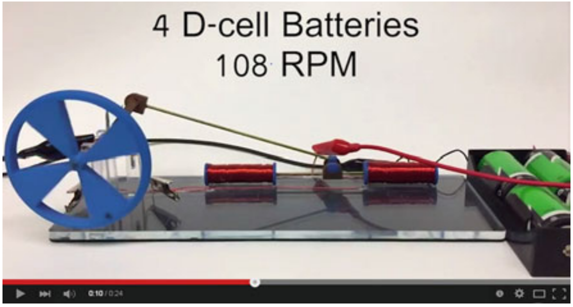


Fig. 9.11 Science students are challenged to optimize the trade-off between speed and duration of operation using a reconstructed version of the Charles Page engine

Table 9.5 Sample pacing schedule

Topic	Days	Dates
Third quarter benchmark assessment (includes pre-assessment items for next unit)	1	April 6
PS. 10 force, motion, & work	9	April 7–17
PS. 11 electricity & magnetism	6	April 20–28
Post Test	1	April 29

member of the team will already be knowledgeable about the design and construction of the motor. Second, the enthusiasm of the engineering students for this activity may increase engagement and interest across the entire class. The engineering class is one of the few classes with a mix of students of all ability levels. Some of the leaders in engineering class are students who are not academically gifted otherwise. Many of them find themselves in a leadership role for the first time.

The engineering objectives in the engineering class must be aligned with the science objectives in the science class. In order to ensure that the reconstructed motors fabricated in engineering class are available in the physical science class, the schedules and pacing guides for the two classes must be coordinated. This adds additional complexity to the scheduling process, but makes it possible to change the instructional method used in science class to a hands-on project-based learning (PBL) approach (Thomas et al. 1999).

The historical reconstruction invention kits used in this process are designed to address the same topics in the same amount of time as the pacing guide previously specified. This comparable pacing is accomplished by replacing multiple separately taught experiences with a single-integrated experience in the context of the invention. Currently the pacing guide provides 4 weeks to cover force and motion topics, and electricity and magnetism topics. A sample pacing schedule for the current year is outlined below: (Table 9.5)

The electric motor kit is designed to be adjusted along a number of parameters to optimize its operation. This process provides a natural introduction to amperage and voltage, introduced in an authentic context. Most students experience difficulty in differentiating amps and volts in a manner that they internalize and retain. This approach introduces the concepts in a manner that has immediate application, allowing students to develop an intuitive understanding prior to formal definition, which is at the foundation of inquiry-based learning. The Electric Motor Invention Kit currently covers the checked topics in the electricity and magnetism standards: (Table 9.6)

In the past, the demonstration electric motor was only used to address one objective ("Objective f. motors"). Using the electric motor invention kit to address multiple objectives, it becomes possible to offer students a hands-on experience in the same amount of time that was previously used for a lecture-style class.

Table 9.6 Topics covered using electric motor invention kit

Covered	Electricity & magnetism topics required by standards
	a. Static electricity
•	b. Current electricity
•	c. Circuits
•	d. Relationship between electric current & magnetic field
•	e. Electromagnets
•	f. Motors
•	g. Generators
•	h. Conductors
	i. Semiconductors
•	j. Insulators

9.3.7 Learning Outcomes

Desired learning outcomes in the Lab School involve both objectives related to content of specific classes as well as goals related to workforce development. Recent reports point to the promise of a new economic driver as we strive to compete in a global marketplace: advanced manufacturing. Several White House initiatives are underway to support the development of advanced manufacturing capabilities, including the Advanced Manufacturing Partnership Steering Committee 2.0 and the Public-Private Manufacturing Innovation Institute. In addition, a number of state and local initiatives are designed to build capacity in this area (Boston Consulting Group 2013).

These initiatives address the development of a workforce adequately prepared for employment as this sector grows. The Bureau of Labor Statistics (2012) reported that 8.8 million new “middle skill” jobs will be created before 2022 that do not require postsecondary education, but that do require technical skills like those needed for advanced manufacturing. An advanced manufacturing trajectory that begins in elementary school can be used to develop a curricular pathway aligned with career readiness objectives.

This provides students with the opportunity to begin forming these skills in the context of classes in science, engineering, and art, and continue developing them through engineering classes at the middle and high school level. In the Lab School, engineering courses in middle school lead to dual enrollment courses at the high school level. This allows high school students to earn community college credits toward an associate’s degree in engineering at Piedmont Virginia Community College. Students who earn an associate’s degree with a grade-point average of 3.4 or above are automatically admitted to the third year of the engineering program (typically mechanical engineering) at the University of Virginia if they wish to continue. This alignment requires a significant degree of coordinated planning among the school system, the community college, and the university.

In addition to the long-term workforce development objectives, specific learning outcomes and instructional objectives are incorporated into each class. These objectives are specific to each discipline. That is, instructional objectives related to engineering are incorporated into the engineering course (for example), while instructional objectives related to science are incorporated into the science course.

- *Engineering Course: Engineering Objectives*
  In engineering, the goal is to determine the impact that use of advanced manufacturing Invention Kits has on students' understanding of basic engineering principles. This understanding is assessed by: (a) quantitative measurement of learning outcomes by students on the ITEEA middle school engineering standards and (b) performance-based assessment through development of student portfolios.
- *Science Course: Science Objectives*
  In science, the goal is to determine the impact that use of Invention Kits has upon students' understanding of related physical science principles. This understanding is assessed by: (a) quantitative measurement of learning outcomes by students as determined by content specific assessments and by (b) related standards of learning for physical science.

If student achievement is at least comparable to traditionally taught classes while students simultaneously gain valuable workforce readiness skills, this might be judged a worthwhile outcome. Preliminary data suggests that students can actually gain a better understanding of science and engineering concepts in comparison with traditionally taught classes. This data will be reported as future cadres of students complete their courses of study that incorporate these new technologies.

9.3.8 Extensions to Informal Settings

Some schools may not have a formal engineering class. However, there are a number of ways in which comparable activities could be implemented in middle schools that do not have an engineering class or comparable "Career and Technical Education" (CTE) offerings. One possibility is to develop comparable experiences through after-school clubs. Many schools participate in robotics programs, for example, that could be adapted to incorporate this experience.

The Lab School is also exploring integration of advanced manufacturing technologies into an after-school mentoring program for at-risk girls, the Young Women Leadership Program. The girls in this program and their mentors are successfully using 3D printers and other related technologies in a variety of STEM projects and applications. The widening popularity of the Maker movement offers similar opportunities for establishment of informal clubs that can be used to develop materials that support science classes. Finally, middle schools without engineering classes could also engage in cross-school collaboration. In one instance, students in an engineering class at one school are developing kits and materials that are being used in a science class in another school.

Some of the Lab School art teachers are successfully incorporating these tools and methods into formal art classes as well as informal experiences outside school. One art teacher, for example, used a prototype electric motor invention kit to support students who used them to create kinetic sculptures. This is an example of the growing trend of integrating art into STEM to create STEAM activities.

Some science teachers participating in pilot work have incorporated construction of inventions into their science classes. Not all science teachers will want to do this or have the time. We therefore developed a model in which invention kits could be constructed outside science classes. However, some science teachers prefer to incorporate construction of inventions into their classes, so this may also be a viable option in some schools that may not have engineering classes. This is aligned with the Next Generation Science Standards (NGSS) that call for the integration of engineering design activities into science instruction (National Research Council 2011).

9.3.9 Logistical Planning

Establishing digital manufacturing processes in which an instructional apparatus designed and fabricated in one class (e.g., engineering) is used for instruction in another class (e.g., science) requires planning and coordination of both schedule and budget. The parts list below lists the fabrication time and materials cost required to 3D print the components for the Charles Page "Electromagnetic Engine" kit using a Stratsys uPrint 3D printer. (Note: the switching contacts, armature, axle, and connecting linkage are metal, and therefore are not 3D printed.) (Table 9.7).

The cost to print a single electric motor kit is approximately \$30. The time required to print the components is about 5 h. The number of 3D printers available will determine the total time that must be reserved to print the components of the kit. For example, if the kit takes 5 h to print, and one 3D printer is available, a total of 50 h will be required to print ten kits. If two 3D printers are available, a total of 25 h will be required.

Similarly, the amount of filament required to print each kit will determine the number of rolls of filament that must be ordered and reserved for the activity. If one roll of filament is required to print five kits, then two rolls of filament will be required to print ten kits. There are further trade-offs. The cost of a roll of filament for a MakerBot printer is approximately \$50 per roll. The MakerBot does not have the capability for printing dissolvable support material, and therefore the time required to remove the necessary support material once the print is completed must also be factored into the equation. A uPrint 3D printer can print dissolvable support material that will dissolve in a bath of sodium hydroxide. However, filament for the uPrint is approximately \$250 per roll. Savings in time can be achieved in return for a significant increase in materials cost (Table 9.8).

Table 9.7 Parts list: Charles page electromagnetic engine

Component	Material cost	Fabrication time
Solenoid assembly		
Solenoid winding tubes	$5.20	1 h 33 min
Armature	n/a	n/a
Armature pivot connector	1.12	0 h 43 min
Commutator assembly		
Flywheel	18.64	2 h 11 min
Axle	n/a	n/a
Switching contacts	n/a	n/a
Axle supports	0.32	0 h 02 min
Switching contact supports	0.16	0 h 01 min
Connecting assembly		
Crank slider mechanism	1.52	0 h 32 min
Connecting linkage	n/a	n/a
Base	1.92	0 h 12 min
Total cost & time to fabricate	*$29.20*	*5 h 15 min*

Table 9.8 Laser cutter versus 3D Printer Costs

	Material used	Material cost (1)	Class set (10)	Fabrication time (1)	Class set (10) (h)
Stratasys uPrint	ABS plastic	$30	$300	5 h 15 min	52
Stratasys Makerbot	ABS plastic	6	60	7 h 30 min	75
Laser cutter	Acrylic	3	30	0 h 15 min	3
Laser cutter	Plywood	1	10	0 h 15 min	3

The cost to create the same parts from a sheet of plywood using a laser cutter would be about a dollar and would take about 15 min. Thus, a class set could take as many as 50 h to print at a cost of $300 or as little as 3 h to fabricate at a cost of $10 depending on the materials and fabricator used. In this application, the 3D printer has advantages for prototyping the design. However, once the design is finalized, the laser cutter is better suited to production of class sets both from the perspective of time and cost.

Resin-based casting is another option that may be suited to some applications. In this process, a silicone mold is made using a prototype of the object to be fabricated. Resin is then poured into the mold to create a plastic part that is a duplicate of the original. Resin can be acquired for about $20 per quart, making this a relatively affordable manufacturing technique that lends itself to production of multiple copies. It can also be undertaken without advanced technology or digital fabrication equipment, making it a good starting point for schools with limited resources (Fig. 9.12).

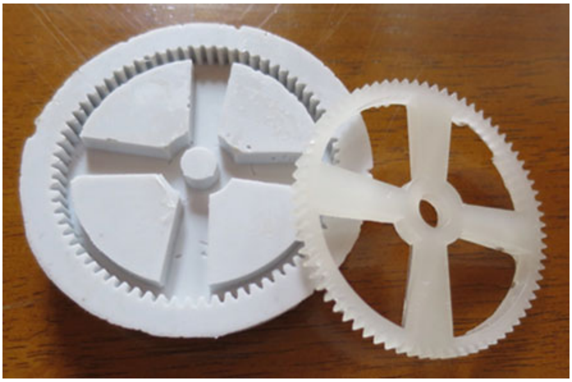


Fig. 9.12 A resin-cast gear

Once the kits have been fabricated, the engineering teacher must then determine the number of class periods that will be required to assemble the kits. Typically about three class periods would be required to assemble the electric motor kit. These 3 classes (47 minutes/period) must then be incorporated into the pacing guide for the engineering class at a time that is both instructionally appropriate for those students and that will also result in completion in time for subsequent use in the science class.

This coordination requires significant planning by both principals and building leaders as well as teachers. However, it makes an instructional activity feasible that would have been economically prohibitive without access to advanced manufacturing technologies.

In this particular instance, a solenoid engine kit aligned with science, engineering, and social studies instructional objectives previously was not available at any price. The advent of rapid prototyping equipment now makes it possible for educators to design and implement new instructional devices at the working interface where teaching occurs. Teachers and their students can potentially become co-constructors of knowledge, harnessing a previously untapped resource.

The capability for educators to use advanced manufacturing technologies to design instructional devices that are aligned with educational needs increases the probability that these activities will be effective in achieving desired learning outcomes. Further, once an activity has been developed and validated, the availability of digital manufacturing technologies means that it can readily be shared and replicated by other schools.

The scheduling and economic planning involved also offer opportunities to give students experiences with important aspects of common industrial processes, allowing them to use engineering tools and mathematical computations in authentic contexts. The Lab School has attempted to schedule common planning periods for teachers who are coordinating their work. This has made it possible for engineering and science teachers to coordinate fabrication of demonstration apparatus in engineering class that will be later used for laboratories in science class.

9.3.10 Professional Development

Professional development is a crucial factor that must be incorporated into successful integration of advanced manufacturing technologies in K-12 schools. National guidelines call for integration of engineering into science teaching. Digital manufacturing offers opportunities to do this in an authentic way. However, few science teachers have had even one engineering course. Therefore, professional development is a prerequisite for successful implementation of engineering activities.

Professional development related to advanced manufacturing technologies involves 2 components: (1) engineering content and (2) pedagogical issues associated with use of these technologies in each content area. The first type of professional development—engineering content—will be similar for all teachers. Instruction on use of CAD programs is much the same for art teachers and science teachers. However, instruction on pedagogical issues is unique to each content area. In science, professional development may be related to use of advanced manufacturing technologies to explore Newton's laws, while in art the learning objective may be the esthetics of motion.

Integration of these technologies into the existing curriculum is not a trivial task. Each instructional module that has been developed in the Lab School has required more than a year of coordinated planning by a team of educational specialists prior to initial pilots in the classroom. This work would be challenging for any single teacher to accomplish alone. During initial phases, significant professional development time needs to be set aside to allow teachers to undertake this type of curricular planning as a team. This is perhaps the single most critical factor that determines the success of pilot implementations.

9.4 Conclusion

Schools are rapidly acquiring digital fabrication technologies such as 3D printers. During the initial phases of acquisition, this is often undertaken by individual teachers who are early adopters of new technologies. Leadership and planning are required to make potential long-term educational gains possible, with particular attention devoted to curricular objectives in each content area.

In addition to potential benefits related to student achievement, adoption and use of digital manufacturing technologies can allow students who may be first exposed to digital fabrication technologies in elementary school to determine whether they enjoy the field of engineering, and to enter this field if their interest continues. Digital fabrication activities may spark an interest in engineering in general and a better understanding of what engineers do, thus demystifying engineering and helping students see themselves as capable of pursuing studies and careers in science and engineering.

Many others will not adopt this as a professional career, but will find it fulfilling in their personal lives through activities ranging from design and fabrication of art and jewelry to hobbies such as robotics. They will also possess an elevated capacity for numeracy and spatial visualization and have better appreciation for physical scales and their relative importance. The continuing expansion of the Maker Movement is evidence of ways in which these skills can be used for personal fulfillment in much the same way as other creative endeavors ranging from art to music currently do. This can lead to interests and skills that will support on-going life-long learning.

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Chapter 10
The Critical Role of Leadership for Education Transformation with Successful Technology Implementation

Martina A. Roth and Jon K. Price

Abstract The attention governments around the world pay to education illustrates a powerful key to unlocking socioeconomic opportunity and building a foundation for a successful future, provided it offers equal access for quality education for all, anytime, anywhere, just in time, and it prepares future generations with qualified teachers and a learning environment to succeed in the knowledge economy, thus contributing to national competitiveness and global citizenship. Access and Quality Education for All is a major challenge for governments worldwide and requires strong leadership at the national (government), regional, school, and classroom level, embedded in a system wide approach of education transformation, enhanced by utilizing public private partnerships. The Intel Education Transformation Model is a proven model implemented around the globe. Grounded in research, this model provides a holistic framework that encompasses seven essential, interdependent vectors: Leadership, Policy, Teacher Professional Learning, Curriculum and Assessment, Information and Communications Technology (ICT), Sustainable Resourcing, and Research and Evaluation. The model reflects evidence-based best practices that have emerged from Intel's collaborations with governments and school systems in more than 100 countries desiring to advance their education systems and improve student learning with effective use of new technology. Using this model, stakeholders can address the practicalities of resource allocation, motivation, and learning progress. A meta-analysis of multiple evaluation reports and studies describe Intel's process of applying a strategic professional development seminar for school leaders and discuss the systemic factors associated with understanding classroom level change. A synthesis of these studies illustrate the

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effectiveness and impact of the Intel Teach Leadership Forums in informing and supporting school leaders, as well as the role of school leaders in the successful implementation of Intel Teach and Learning courses in their school and the implementation of the training strategies following the course. Results from deployment research and Leadership Forum participant survey and interview data provide evidence of immediate outcomes and longer term impact of professional development courses for leaders, such as increased support through funding, time release, priority status, interest, and involvement. In addition, findings from these studies highlight the impact that leadership has in facilitating whole school change toward effective technology use across the curriculum.

Keywords Leadership and Policy · Education Transformation · Systemic change · Teacher Professional Learning · Curriculum and Assessment · ICT-Information and Communication Technology · Research and Evaluation

10.1 Introduction

Across the globe, discussions are taking place about the challenges that education systems are facing in transforming the classroom into 21st Century learning environments that prepare students for life, work and society. Innovative practices and assessments on how to most effectively develop 21st Century skills like critical thinking, problem solving, collaboration, decision making, communication etc. are being developed, and education reformers are exploring new ways to share and create knowledge—individually and collectively. Governments joined by NGOs, municipalities, academics and the private sector are sharing ideas and experiences on how to improve education systems worldwide. The improvement of leadership, policy, professional development for teachers, assessment of student results, curriculum change etc. are high on the global agenda, with a special emphasis on leadership across cycles (national, regional, school)—be it the annual World Forums for Education in London, the annual UNESCO Mobile Learning Week, the annual WISE Conference in the Middle East, or the recent UNESCO Education World Forum in Korea 2015, addressing the Post-2015 Education Agenda.

Each conversation expresses big expectations for technology—its effective integration, innovative methodologies, and impact on the quality of teaching and learning in today's classroom, as well as on summative and formative assessment and evaluation. A recent education ministry level gathering took place in Qingdao, China, as the International Conference on ICT in Post-2015 Education, where all stakeholders committed to jointly drive ICT in Education forward and make Equity and Quality Education for All and Lifelong Learning an achievable goal for 2030. There is an agreement that as the demand for high-level subject-based skills and higher order twenty-first century skills continue to grow within schools and beyond, for future employability and socioeconomic growth, the tasks associated with transforming traditional models of formal and informal learning (in and outside schools) to meet these demands are often embedded within complex political, social, and educational systems. Increasingly governments, non-governmental organizations, private sector, academia, educators, and practitioners have been establishing public–private partnerships to address challenges and opportunities associated with the numerous education reform efforts. Multinational corporations, with their global presence, needs as employers, global corporate citizenship, and agents of innovation, provide perspective, programs, expertise, and experience that can help local governments and agencies intent upon transforming learning environments and learning outcomes.

Intel® Corporation is a global partner to national governments, global and national NGOs, and academia and contributes to the development of modern, high-quality educational systems worldwide, to help prepare young people for the twenty-first century, and to adopt global standards to meet local requirements. Intel's involvement in a countries Education system is primarily driven by government request. The collaboration with Ministries of Education, Ministries of ICT, Ministries of Culture etc. is based on the principle of a Public–Private Partnership (PPP), which also takes into consideration the amount and degree of localization needed.

A core component of Intel's holistic approach to support Education Transformation is the development, dissemination, support, and evaluation of the Intel® Teach portfolio of professional development programs. These programs are designed to provide teachers with the knowledge and skills to develop twenty-first century skills with their students, encourage project-based, collaborative and personalized learning and effectively integrate information and communication technologies as critical tools into the classroom. Identification of the activities that support a shift from traditional education systems to the desired innovative, project-based, collaborative and personalized, adaptive learning environment requires exploration beyond the classroom to include the wide-ranging systemic change of programs, practices, and policies based on the application of a clear theory of change.

The goal of this paper is to discuss effective leadership and strategic professional learning design for successful technology implementation adopted by the Intel® Education initiatives that recognizes, among other critical aspects, the critical role of leadership. By referencing established deployment research and programmatic evaluation findings, the Intel® Education strategies will be discussed, to assist leadership in the larger, systemic factors associated with understanding classroom level change.

10.2 Background

Intel® Corporation is one of the world's leading technology companies and has been inventing and delivering world-changing innovative technology solutions for nearly five decades, and since its foundation it is committed to give back to the society, with a passion for education. In the increasingly global economy, Intel recognizes that curiosity, innovation, critical thinking, problem solving, and a quality education for all are necessary to prepare tomorrow's workforce for jobs of the twenty-first century and global citizens.

Intel® Education is a learning partner with a decade of achievement in promoting education excellence and has worked with institutions and educators worldwide, creating comprehensive programs and solutions based upon experience and insight, and embedded in comprehensive concepts like the Intel® Education Transformation Model. Intel's Education solutions are flexible to meet local needs, but are unified by the common theme of promoting student success by providing the right solutions and tools for enabling education transformation in schools around the world.

As a testament to Intel's continuing commitment to education over the last 10 years alone, Intel has invested over $1B into education projects based on scalable, sustainable strategies, like public–private partnerships worldwide, including primary and secondary education, higher education and lifelong learning.

To monitor and sustain continuous improvement of these educational initiatives worldwide, Intel® has invested in research, rigorous program evaluation, and student assessment. The research and evaluation compiled for this purpose has not only enabled the improvements of the program development efforts, but also comprises a comprehensive body of evidence that demonstrates program impact (Michalchik et al. 2009). As a result of these efforts, critical evidence has emerged that may inform other evaluation activities designed to measure impact related to ICT in education in terms that extend beyond logistical measures and traditional student assessment.

10.3 The Holistic Approach to Systemic Transformation

With an emphasis on student-centered, personalized, project-based learning, and the development of twenty-first century skills (i.e., critical thinking, problem solving, collaboration, decision making), students begin to develop complex thinking and creativity, innovation, and communication skills and are empowered to become lifelong learners. Studies show that with teachers undergoing regular professional development, making effective use of ICT and new pedagogies in the classroom, and increasingly becoming a guide and mentor for their students, students are learning with higher motivation, increased engagement, and longer hours (Hightower et al. 2011). Connecting instruction to technology increases access to content, improves avenues for communication, interaction, and assessment, and enables teachers as well as students to expand their opportunities for learning, community engagement, and career possibilities.

Based on more than a decade of research on (1) education transformation around the world and (2) e-Learning deployment research in selected countries, as well as (3) evaluation data and reports collected from studies of successful ICT leadership development seminars in schools over five years, the contextual factors regarding

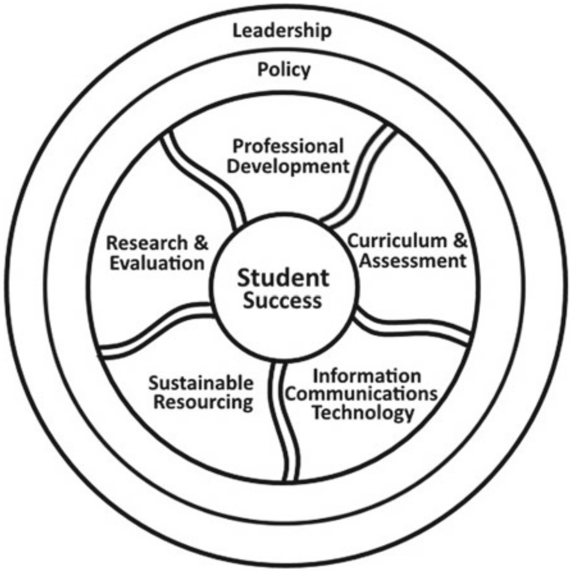

Fig. 10.1 Intel education transformation model (Intel 2015a, b)

how schools can effectively integrate ICT is examined in this chapter. The Intel Education Transformation Model, (Fig. 10.1) related workshops and tools, and the Intel Teach Leadership Forums for K12 administrators were created by Intel® Corporation for educational leaders to help promote and support successful technology integration in schools, districts, and countries. Components of this model include: professional development, research and evaluation, curriculum and assessment, sustainable resourcing, and ICT, supported by leadership and policy. For the purpose of this paper, we will focus on leadership.

10.4 Leadership Guiding Systemic Change—National, School, Classroom Level

Strong leadership is essential to ensuring that technology-enabled learning becomes a permanent part of the educational experience—and outlasts the policy makers who introduce it. True transformational change requires powerful leadership across pedagogy, curriculum, policy, and more. Effective leaders inspire strong-minded individuals with widely differing viewpoints to work together—and instil the confidence that instituting change across a complex system can be done. For success, a comprehensive leadership concept is needed on national, regional, and school level, and countries and institutions are advised to develop and implement a flexible, comprehensive leadership plan that extends across all aspects of the Intel Education Transformation Model (Intel 2015a, b).

Leadership occurs across multiple levels: Macro, consisting of the national or provincial ministry of education that sets overall policy, curricula, and national assessment; Meso, consisting of school-level leadership involved in the day-to-day decisions; and Micro, leadership viewed at the classroom level (Price and Roth 2010).

Leadership at national and regional level: successful transformation of the education system can only happen with powerful, committed leadership at governmental level (national and regional/district level). It starts with the development and communication of a shared vision and defining stakeholders' mission by country leaders, followed by the creation of and commitment to a transformation master plan (long term) including strategy design and multi-stakeholder partnerships. Transformation continues with the implementation of initiatives, with management and plans for sustainable resourcing, followed by solid monitoring and evaluation processes that include communications and recommendations to inform improvements in goals, processes, and next steps. (Hinostroza et al. 2014). Countries that are demonstrating leadership in education transformation are showing improvement in student performance, learning motivation, and engagement. For example, at the Macro level, the Organisation for Economic Co-operation and Development is showing results in PISA (summative assessment), national assessments as well as formative assessments in classrooms (OECD 2013).

Leadership in schools and classrooms: Within the Meso and Micro levels, a principal's leadership and support is crucial. According to the report of the second information technology in education study, (SITES M2), (Fig. 10.2), principles act as facilitators or gatekeepers of innovative technology & pedagogical practices (Kozma 2003). The principal's support as illustrated in the model shows that not only is the leadership support of teachers essential, but also support of the innovation itself. As a result of the teacher interviews and classroom observations of the

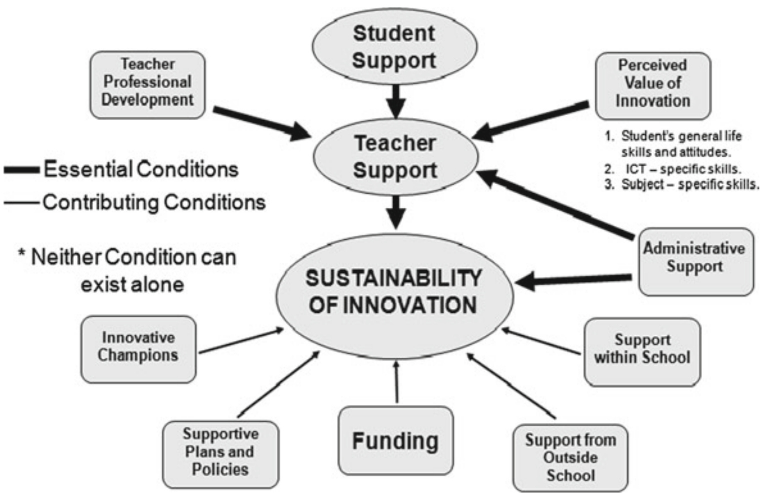

Fig. 10.2 Explanatory model of sustainability

Intel Teach programs, the support required from school leadership becomes evident. Student-centered, project-based learning challenges the traditional classroom teaching methods. Often, we have observed school leaders question a classroom environment that includes students out of their seats, interacting in groups with teachers moving about the classroom interacting with groups of students. This collaborative, project-based environment is drastically different from students sitting in orderly rows with the teacher at the head of the class lecturing. Without understanding of this new dynamic, the classroom could appear "in chaos" resulting in the Principal interfering to return "order" to the classroom.

Most recently, Intel conducted a series of classroom environment case studies to explore the contextual factors associated with effective use of ICT in the classroom. The findings from this study suggest three observations of the role of school-level leaders in supporting a process of ICT integration and pedagogical innovation:

1. The leadership does not come only from the principal. In most of the schools, there were other figures who were strong leaders or advocates for technology and ICT focused teacher professional development.
2. The leadership consists of more than establishing a vision and providing clear expectations for teachers, they provide support and guidance in teachers' classrooms. Most of the teachers had no prior experience with the activities they were being asked to do, and in each of the schools observed, the principals, technology coordinators, and trainers were consistently inside the classrooms with support, suggestions, and encouragement.
3. The leadership consists of solving specific administrative and logistic challenges regarding ICT use. Again, in each of the schools observed, there are resource limitations on time, infrastructure, staff, space, and funding. In each case, the administrators had to find solutions to allow change and innovation to take place with the resources that were available.

ICT infrastructure is a constant challenge, especially for schools in developing countries. The decisions administrators have to make are often frustrating because they cannot provide all students all the access that is desired (Light et al. 2009).

10.4.1 Transformative Policy

Today, effective policies across the school, state, and national levels must align to encourage innovation and empower educators to use information communications technology (ICT) in ways that enhance teaching and learning.

Next-generation policies must balance flexibility and innovation with accountability and consistency, with an increasing emphasis on data privacy. This includes data collection and access, how it is used and stored, and how to manage potential breaches.

An effective policy framework aligns with all aspects of the Intel Education Transformation Model to reflect the full scope of the educational technology initiative and establish a flexible framework that achieves innovation and accountability while promoting the transformative use of ICT (Intel 2015a, b).

10.4.2 Professional Development

Professional learning and teacher readiness are pivotal to supporting education reform and transformation. That is why Intel provides training, tools, and ongoing support for educators worldwide. With evidence-based tools and resources, today's teachers are empowered to create modern, student-centered learning environments that engage students, integrate technology, and build twenty-first century skills.

The Intel Education Transformation Model outlines how the right professional development can help teachers and education leaders support a technology-infused learning environment, apply new learning strategies, and deliver a personalized education for each student (Intel 2015a, b).

ICT is a tool, and in education ICT can enable change at an accelerated rate, transforming the activities within the classroom depends on the teacher's knowledge, attitudes, and behaviors. Following recent advances that allow ICT to be more available and mobile, there is increasing use of technology in education. Over the last several years, the demands on the teaching profession have increased. Much of these challenges are due to increased accountability requirements. As a result of these shifts, the demands on monitoring the accountability requirements have increasingly fallen upon the school leadership. In turn, the preparation of teachers has received much attention from both researchers and policymakers alike. While some studies indicate the answers to teacher preparation can be found through developing advanced content knowledge, others suggest the need to require advanced degrees will improve teacher preparation (Johnson et al. 2005). Yet, additional research indicates that factors such as working conditions, which include class size, administrator support, peer support, and student discipline, are associated with teacher preparation (Johnson et al. 2004).

Intel has spent a great deal of time, effort, and money studying effective teaching and learning, and has chosen the approach that one of the best investments a government can make to improve student learning is to invest in teacher professional development and policy workshops. Access to technology without systemic supports such as policy, curriculum alignment, assessment, and leadership that does not have a strong teacher professional development and support strategy will only lead to disappointing results. In a 2003 article titled "Resources, Instruction, and Research," the authors discuss the importance of the interactions and processes that surround classroom instruction, saying, "Teaching is what teachers do, say, and think with learners, concerning content, in particular organizations and other environments, in time" (Cohen et al. 2003, p. 124). Therefore, any effort possible to support teacher's knowledge, attitudes, and behaviors in shaping classroom instruction and collaboration are critical.

Further evidence to support the importance of teacher professional development is the SITES-M2 study of innovative pedagogical uses of technology. This study examined 174 schools in North and South America, Africa, Europe, Asia, and Australia. This study identified "Essential" and "Contributing" conditions underlying sustainable innovative pedagogical practices of technology use. Essential conditions, as identified by the research, were those conditions that were necessary for sustained innovation but were insufficient to act alone. Essential conditions for sustainability require support from three main actors: teachers, principals, and students. Contributing conditions were those found to facilitate the innovative practices, as identified in Fig. 10.1, (Kozma 2003).

Most notably, the primary condition for sustaining an innovation is teacher support. Without teacher support, the innovation simply cannot occur. As reflected in the model, essential contributions to teacher support include: the perceived value of the innovation, professional development, and student support. More specifically, as stated by Fullan and Hargraves, "However noble, sophisticated or enlightened proposals for change and improvement might be, they come to nothing if teachers don't adopt them and translate them into effective classroom practice", (Fullan and Hargraves 1996). As such, teachers must understand the relevance of the proposed change, the benefits to the students, and receive sufficient professional development that provides transformation of the teacher's knowledge, attitudes and classroom behaviors.

10.4.3 Research and Evaluation

Conducting thorough, well-planned research and evaluations can help inform how well an educational technology initiative is working, and build on successes. As an opportunity to develop and achieve measurable goals and gather evidence of progress, research, and evaluation creates a cycle of improvement beginning in the early planning phase of a technology initiative, utilizing evidence for to investigate clarity of an intervention, contributing factors, identify flaws, and celebrate successes within a cycle of continuous improvement. The resulting evidence enables data-based decision-making, reform, and continued funding for successful interventions (Intel 2012).

10.4.4 Curriculum and Assessment

To reach a transformed learning environment where students become active learners and problem solvers, curriculum must be modernized to include digital learning while assessment strategies balance skills with progress to improve student success.

A modern curriculum framework encompasses both subject-matter requirements and twenty-first century skills such as collaboration, communication, and critical thinking—and the assessment strategies behind them must evolve alongside. Summative and formative assessment that allows continues feedback for teachers and learners to adapt teaching learning methodologies, for steady students' learning progression. By using Big Data analytics to provide real-time information about students' behavior and academic progress, teachers and school administrators can make better informed decisions and empower them to react to the students' progress. Technology enables this use of analytics with its capacity to display data based on teaching strategies, lesson plans, and content that offer standards-based, student-centered learning experiences (Intel 2015a, b).

10.4.5 Sustainable Resourcing

Securing long-term sustainable resourcing for technology requires a comprehensive approach that covers all aspects of education transformation, from the ICT environment, services, and support to professional development, curriculum, and beyond.

Successful educational technology initiatives should be focused on sustained improvements in student outcomes. Despite funding challenges, ministries of education, state governments, and other funding bodies are advised to holistically integrate ICT-enabled learning into long-term planning and operating budgets. Universal service funds are another proven source. The integration of public–private partnerships with all stakeholders bringing in competencies, experiences, solutions, and values, have shown successes gained from strategies resulting from a practical, comprehensive plan, and budget that is designed to secure long-term ICT funding. (Intel 2015a, b).

10.4.6 Information and Communications Technology

With the right information communications technology (ICT) tools in place, relevant teaching, learning, and assessments for the modern classroom can be put in place. Successful digital learning environments combine the right devices with quality education software, broadband connectivity, a robust IT infrastructure, and secure cloud services. The right ICT solution improves education results through productive solutions, improved communications, collaboration technologies, and professional development communities, and advanced analytics tools.

There are a number of sources predicting what impact certain technologies will have on education. The following are ubiquitous across most of the analyses, always a highlight however, is that the teacher is most critical to guide and mentor personalized and team learning activities:

- *Social Media & Learning Communities*: sharing resources, advice etc. through online properly moderated communications via social media should be part of the education world both inside and out of the classroom and facilitating real-time teacher and student communications. Professional communities like the Intel® Engage platform for teachers includes access to free professional development, webinars and tools, to share information and work collaboratively.

- *Online Education Resources*: a vast array of content is available on the Internet today. ICT allows teachers and students to connect with those resources, with experts, and other schools and students. For that, the students need to be educated though to find and filter data, use skills such as evaluation and problem solving, critical thinking, innovation and creativity, and the ability to work collaboratively and communicate effectively.
- *Hybrid Learning Models*: Students are engaged with web based content in the classroom and at home, they are expected to create, not just consume, and develop problem-solving skills. They are being exposed to learning with new models like the Flipped Classroom and Massive Open Online Courses [MOOCs]. They are expected to collaborate with their classmates and become skilled in presenting their work to teachers and peers. And all of this is aimed at equipping them to be self-directed, lifelong learners. Class time is used for mentoring and project-based working time.
- *Online and Personalized Learning*: with technology available, personalized instruction is easier for teachers. They adopt new education models, and increasingly become more facilitators and mentors in the classroom. Meanwhile, they are being held to higher standards for student outcomes. By applying reuse and adaptive learning technology, the learning experience can be personalized for each learner and allows to "create their own view of the world". They absorb process, store, and retrieve information in their own way. The goal of personalization is to empower the learner to become the masters of their educational destiny (Intel 2015a, b).

10.5 A Model for Strategic Professional Development

10.5.1 The Intel Education Solutions

Intel Corporation is committed to strengthening education systems and teacher readiness and recognizes professional development as critical success factors for education reform and transformation. For over a decade, Intel has delivered ongoing teacher professional development to more than 15 million teachers, in 35 languages, in 70 countries around the world. That experience has helped make Intel a trusted advisor when it comes to delivering the professional development educators need to create classroom environments and personalized learning experiences that power student success (Intel 2011).

In addition to software, and device reference designs, Intel delivers robust, flexible, and sustainable solutions that empower educators to create classroom environments and personalized learning experiences that support student success. These solutions range from recognizing excellence in engineering and technology at events such as the Intel Science Talent Search and Intel Science and Engineering Fair, to initiatives such as Maker Education and equity and access programs such as its Girls and Women Initiatives (Intel 2015b).

The professional development programs are designed to assist teachers with the integration of technology into everyday classroom practice. The goal of the training is to help teachers integrate ICTs effectively into their teaching practice by emphasizing student-centered and inquiry driven learning activities. These programs consist of the Teachers Engage online community, twenty-first century Teaching Resources collection of online learning activities, the Intel Education Mobile Learning resources collection of tools and materials, and the numerous global education partnerships designed to articulate and demonstrate the potential for new pedagogies within a technology-rich learning environment. The core of the professional development programs, however, are the Intel Teach courses.

The core Intel Teach curriculum is the creation of a unit plan, including model student work samples, support materials, and an implementation plan. This structure allows teachers to expand their technical skills in the context of a curriculum development process. The process of designing the unit plan is intended to give participants a chance to think deeply about the issues involved in integrating ICT into their teaching. By stipulating the creation of immediately relevant materials, the curriculum puts the teachers' classroom needs at the center of the training experience to understand ICT as a critical tool to encourage active student learning.

10.5.2 The Intel Teach Leadership Forums

Government partnerships and knowledgeable leaders are critical to the partnerships designed to promote student-centered, personalized, and collaborative teaching and learning worldwide. Specifically, principals play a vital role in setting the direction for innovative technology and pedagogy, but existing knowledge on the best ways to prepare and develop highly qualified principals is sparse (Darling-Hammond et al. 2007), Intel initiated an effort to build upon Intel Teach professional development course aimed at classroom teachers. The Intel Teach Leadership Forum is a program designed for school- and district-level administrators. With the important role administrators play in supporting teachers' efforts, the training experience was developed to guide K-12 instructional leaders in their efforts to plan and implement technology integration and professional development in their schools and to promote twenty-first century learning in the classroom, especially those schools that previously had participated in the teacher training program.

Among other activities, the Forum gave participating administrators the opportunity to examine the critical role leaders play in the effective integration of technology into teaching and learning, and apply their knowledge to create a prioritized list of leadership behaviors that impact the integration of technology as a tool to improve student learning. The curriculum for the course guides instructional leaders as they support and promote effective integration of technology in K-12 classrooms. Through hands on activities in a computer lab, participants engage with research about technology integration and student inquiry as effective approaches to improving student achievement. This 4-hour forum provides direction and options for developing plans that can be implemented to address the unique circumstances of each school or district (Intel 2015a, b).

10.5.3 Deployment Research Data and Results

Intel's Deployment Research results from a multi-year investigation designed to help stakeholders learn from the experience of large-scale e-Learning deployments. The research has impact both locally, in guiding specific initiatives, and globally, in generalizing themes and lessons learned to inform the success of current and future initiatives.

The e-Learning deployments studied featured a diverse set of goals, contexts, and designs. Taking a bottom-up approach to generate a framework that describes a set of important considerations, four broad phases that define the process of significant e-Learning deployment and sets of factors that must be considered by stakeholders in each stage were developed. As a result, the framework offers a shared vocabulary for describing and evaluating e-Learning deployments. The framework, represented by: Vision, Planning, Implementation, and Re-Informing Vision provide guidance to education leadership as they begin e-Learning strategies and education transformation initiatives (Patil et al. 2014).

1. The first phase of any e-Learning deployment is to define the program vision. Multiple factors inevitably shape this vision, including the policy and educational context; goals and priorities for the initiative; the unique personalities and backgrounds of those leading the efforts; and financial realities for implementing and sustaining the initiative.
2. In the planning phase, leaders must define all of the key features of the initiative, including the geographic location for the initiative, roles, and responsibilities for implementing different initiative components from infrastructure to program evaluation, and mechanisms for communicating between stakeholders about all aspects of the initiative.
3. During implementation, stakeholders enact the components of the initiative, from installing infrastructure to deploying technology, using technology in the classroom and at home, providing and participating in professional development, undertaking evaluation, and communicating about progress.
4. The re-informing phase refers to the ongoing process of examining the initiative and its implementation; identifying challenges, successes, and emerging results; and using that information to refine and strengthen all aspects of the initiative.

Of the nine countries studied, promoting reformed and innovative pedagogy is, perhaps the most ambitious goal some of the programs targeted. To achieve deeper reform is a long term undertaking and requires more than just introducing technology. For example, Shanghai's e-School Bag project and Korea's SMART project both sought to foster tech-based, self-directed, twenty-first century learning for students. Both of these one-to-one ICT programs followed other education reform projects that began first, with a re-design of the curricula in both countries and then a roll out of basic but critical ICT infrastructure in schools. In one case, starting in 1998 the goal of Shanghai's "basic education transformation is to promote students' personalized learning, to achieve a higher level of educational equity, and to realize every student's potential to be fully developed" (Zhang et al. 2013, p. 13). Most Shanghai and Korean schools already had computer labs and both teachers and students had basic ICT literacy. Additionally, both initiatives dedicated substantial resources to teacher training and ongoing pedagogical coaches (Chatterjee et al. 2014)

For leaders, a long-term vision may be the hardest goal to achieve within the time frame of a single political administration. The deployment studies found, for example, that Bosnia, Korea, and China each have long-term economic development goals of creating economic growth through the integration of educational technology policy. Each envision that by training people in twenty-first century skills, each country can become a knowledge economy society. Korea is the farthest along in achieving this aim because it has the most established technology infrastructure and one of the most robust educational implementation plans, whereas China is a positive example of a country understanding the relationship between long-term goals and their immediate activities and implementation strategies (Chatterjee et al. 2014).

10.5.4 Programmatic Data and Results

Findings from the earliest formative evaluations of the Leadership Forums indicated that of the total population of participants involved in Leadership Forums identified themselves as school principals (Wexler et al. 2005).

Participant response to the forums were very positive overall with the vast majority reporting they would recommend the forum to a friend or colleague, and that the ideas and skills they learned from the program would help them improve teacher effectiveness and student achievement by supporting and promoting the integration of technology.

A study on the Intel Teach, Leadership Forums conducted in Australia details the findings on how school leaders facilitate and support technology-rich learning environments. The study covers the effectiveness and impact of the Leadership Forums in informing and supporting school leaders in their various roles supporting and conducting successful Intel Teach courses in their school and the implementation of the key learning strategies following the course.

Using online surveys, Leadership Forum participants who completed the program found the program valuable in providing insight into their role as educational leader in the effective integration of ICT in teaching and learning, providing knowledge of the resources and strategies available for supporting professional development, teaching practice and student learning related to ICT integration, and providing the leaders with the opportunity and understanding to begin to develop an action plan for their school (Oakley 2010).

A follow up survey was then distributed to all leaders who had participated in the Leadership Forums in New South Wales. This follow up study was designed to gather information on the impact of the Forums at least 1 year after completion of the course. Of particular interest to the researchers was the integration of technology across the schools and the factors that had influenced the extent of progress.

Participant responses indicate the Leadership Forums had stimulated interest and generated some positive action in most of the schools. A vast majority had implemented aspects of the action plan they had developed during the course, had shared resources and strategies from the forums with other members of their leadership teams and teachers, and had explored the notion of Web 2.0 technologies in teaching and learning (Oakley 2010).

Findings of the study highlight the strong impact that effective leadership can have in facilitating whole school change toward effective technology use across the curriculum. The Leadership Forums provided leaders with significant information, understanding, and drive credited for a positive impact on initiating a technology-rich environment within their school. In addition, Leadership Forum participants also reinforced the notion that integrating technology across the curriculum is more likely to succeed with a whole school approach, endorsed and supported by leaders through funding, time release, priority status, interest, and involvement. The likelihood of funding, professional development time, and recognition for successful teachers was most likely where the principal or deputy principal attended.

One aspect of the study includes review of a strategy that would impact the whole school rather than just reaching the ICT Coordinator (Oakley 2010). The Network initiative involved discussing the approach and the specific requirements of the school in the delivery of the Intel Teach Program principal followed by a discussion to ensure that the most appropriate teachers were selected for the trainer role, identifying the attributes required for success, including credibility with staff, confidence and experience in delivering professional development, implementing a curriculum focus rather than ICT expertize, and the capacity to lead and support staff (Oakley 2010).

The Network Initiative demonstrated the benefits of involving, informing, and supporting leaders in the Intel Teach Program, both during and following the Master Training program. The role of the Senior Trainer in achieving this was most important. As a result, the Network model as endorsed at a Regional level, giving the program additional status which encouraged involvement of school leaders (Oakley 2010).

Overall, the advances made highlight the importance of strong involvement in the Intel Teach Program at a leadership level and the leadership actions that strengthen the move toward effective use of technology across a school, including:

- Well-communicated expectations at a leadership level,
- A consistent, whole school approach to the professional development, curriculum planning, and implementation,
- Suitable technology resourcing, reliability, and support,
- Allocation of time for professional development in place of, rather than in addition to, other staff requirements,
- Streamlining of the requirements through the use of common and user friendly approaches, tools, and templates,
- Close monitoring and sharing of progress and achievements and recognition that there will be different levels of teacher experience, expertize, and willingness that need to be addressed,
- A readiness to act when needs or issues are identified, and
- Emphasis on the compatibility of the approach with school and system requirements, priorities, and initiatives. (Oakley 2010).

10.6 Conclusion

Quality education transforms people. In turn, people supported by new technology transform education. For the transformation to be successful, and improve student learning and progression, strong leadership—on national, regional, school, and classroom level—is required. Future socioeconomic growth and opportunity requires long-term, incremental change, entrepreneurship, and innovation—and young people prepared for these.

The ultimate goal is to promote twenty-first century educational systems that can adequately prepare young people for the challenges today and opportunities of the future. The Intel education initiatives seek to make best use of technology in twenty-first century teaching and learning and to contribute to the improvement of project-based, personalized, and collaborative learning in classrooms worldwide.

Countries currently participating in the implementation of the Intel Education Transformation Model are each at a unique point in the process of building the human capacity, technical infrastructure, and policy environment that will enable educators to make real, lasting improvements in how teaching and learning occurs in their schools and classrooms. As a result, these changes will enable students to become the countries' competitive workforce of tomorrow, nationally committed and global citizens.

With the right tools, leadership can develop an understanding of both issues and processes to initiate change. From vision, to mission, to master plan, implementation, and measuring results and progressions (evaluation and assessment), leadership is needed in all aspects of the transformation process culminating in transparent communications to inform all stakeholders.

By openly discussing best known methods, promoting teacher-, principal-, and administrator role models, and celebrating them in public, or recognizing key learnings from failures, leaders and stakeholders may jointly develop solutions. Formats like global and national Transformation Summits and Forums, school workshops, conferences as well as online webinars and communities, well prepared, sustained, and with concrete action plans regularly monitored and discussed are recommended. Further understanding is possible through ICT deployment research on country, regional, and school levels and evidence from short-term, focused case studies are critical for analyzing a theory of change and go hand in hand with teacher professional development and student assessment. Systemic analysis together with curricular data analytics provides real-time information about students' behavior and academic progress. As a result, teachers and school administrators can make better informed decisions and empower them to react to the students' progress.

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Part V
Promoting Teacher Development by Using ICT

Chapter 11
Exploring the Intel Teach Elements in Teacher Education

Integration and Technological, Pedagogical, Content Knowledge Development

Daniel Mourlam and Mary Herring

Abstract This chapter reviews the integration of ICT through the development of preservice teacher Technological, Pedagogical, Content Knowledge (TPACK), as well as how the Intel Teach Elements (Elements) have been used to develop teacher knowledge of pedagogy and technologies. In this context, results are shared on the use of the Elements course modules within four teacher educator preparation institutions. Presented are those Elements courses and modules that were used, how they were used within teacher education coursework, and how preservice teacher TPACK changed as a result of being enrolled in a course where they were part of course activities. Data were collected through multiple measures, including a pretest/posttest preservice teacher survey and pretest/posttest performance assessment, which allowed for preservice teacher TPACK to be analyzed. An open-ended faculty questionnaire was also used to describe the integration of the courses or modules, faculty satisfaction, and future plans for Elements use within coursework. Results indicated that faculty integrated the resources into face-to-face, blended, and online modes of instruction using them as both a curricular resource and as part of lesson design projects. Results also suggested that preservice teacher knowledge of each of the TPACK constructs increased at statistically significant levels.

Keywords Higher education · Preservice education · Technology integration

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11.1 Introduction

A challenge faced throughout the history of education is only looking to technology and the development of technological knowledge apart from pedagogy and content, as being the path to making twenty-first century learning opportunities a reality. Since the emergence of textbooks, pens, and overhead projectors, schools, organizations, and policy makers have attempted to use technology to improve student learning (Culp et al. 2005). These attempts have been accelerated due to the adoption of the Common Core State Standards and Next Generation Science Standard that often require the development of twenty-first century skills in conjunction with knowledge of content. However, more often than ever, attempts to leverage technology during instruction have not led to increased student learning (Cuban 2001). This result is due primarily to a lack of, as well as lack of development of, teacher knowledge surrounding how to effectively teach with technology. This type of knowledge is called Technological, Pedagogical, and Content Knowledge or TPACK (Mishra and Koehler 2006), which is the confluence of pedagogical knowledge, content knowledge, and technological knowledge. Educator TPACK is developed when teachers are engaged in authentic, problem-solving experiences where they are required to use a technology to complete a task (Harris 2008; Koehler and Mishra 2005). As teachers seek to create environments for their students that foster these key competencies, one approach has been through the use of the Intel Teach Elements (Elements) courses and course modules as a mechanism for teacher development at all levels of the education system.

The Elements courses and modules offer opportunities where learners can interact with others, regardless of location, ability, age, gender, race, ethnicity, and language, to collaborate and problem-solve in creative and authentic ways that have meaning not only for learners, but for a larger community as well. Creating experiences, such as those afforded by the Elements, for educators equips them with the very skills needed for success (Darling-Hammond 2010; Greenhill and Petroff 2010; Kay 2010; Wagner 2012). Often, educational technologies are explored in the development of those experiences (Darling-Hammond 2010; Gardner 2010; Iowa Department of Education 2010; ITQP, In Press).

Seeking to better understand the role of the Elements within teacher education programs, the data presented in this chapter was collected at a time when a number of teacher education institutions were exploring the use of the Elements within their coursework. This work focused on identifying the ways in which faculty were using the Element modules so that future decisions could be made, by a variety of stakeholders, to further enhance the preservice teacher preparation focused on critical new literacies. Given the prevalence of technology's role in creating learning experiences that develop these critical competencies, it was important to determine the extent to which preservice teacher TPACK was developed. Guiding this inquiry were the following research questions:

1. In which Intel Teach Elements courses or modules are the faculty members integrating their teacher education courses?

2. How are faculty members integrating and facilitating the Intel Teach Elements modules into their university courses?
3. How can the development of preservice teacher TPACK be characterized before and after a teacher education course infused with the Intel Teach Elements?

11.2 Technological, Pedagogical, Content Knowledge

Building off Shulman's (1986, 1987) pedagogical content knowledge (PCK) where knowledge of discipline and knowledge of instructional practices were required for success in the classroom, TPACK represents the knowledge necessary for teachers to be able to create learning experiences that effectively leverage technologies. As technologies have penetrated into all aspects of society in the past few decades, so also have they entered the classrooms at all levels with as much prevalence, thus necessitating new forms of knowledge. While PCK has been the dominant construct of teacher knowledge in the past, with the introduction of technologies into the learning process, new forms of knowledge have emerged. These new domains of knowledge include Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and TPACK itself. Understanding each of these three knowledge domains is critical for increasing an educator's ability to teach successfully with technology.

TCK represents the knowledge about how technology interacts with content knowledge in ways that either afford new or constrain representations (Koehler et al. 2007; Mishra and Koehler 2006). TPK, on the other hand, is concerned with the dynamic relationship between knowledge of technology and pedagogy, whereas with TCK, technologies allow or constrict certain instructional approaches (Koehler et al. 2007). TPACK is the confluence of a teacher's knowledge of technology, instructional approaches, and subject matter content knowledge and is the knowledge necessary if teachers are going to experience success when teaching with technologies (Mishra and Koehler 2006; Nore et al. 2010).

Central to the understanding of TPACK is that each of the three domains has a dynamic transactional relationship. As teachers make decisions in any one of the three domains, those changes have a reciprocal effect on the other two domains. Approaching any of the TPACK domains in an isolated way is a misguided approach to teaching with technologies, because technologies must fit within the scope of what is taught and how it is taught (Mishra and Koehler 2006). Therefore, as new technologies enter schools and teachers begin making sense of them, ensuring they have the requisite knowledge and skills to find the appropriate fit for technologies in lessons will be a critical task for teacher education programs and new teacher professional development.

11.2.1 TPACK Development Approaches in Teacher Education

Since the introduction of TPACK, a number of TPACK development approaches have been examined as an effort to increase the efficacy of new teacher development in using digital technologies during instruction. Developing preservice teacher TPACK is a necessary component in preparing them for entry into the K-12 classroom, representing a single component of a systemic teacher TPACK development approach. As institutions have explored how best to develop preservice teacher TPACK, development has occurred in a variety of contexts with a couple of key cross cutting themes.

11.2.1.1 Approaches in Educational Technology Focused Courses

Multiple approaches to TPACK development have occurred in educational technology courses, which are common in teacher education programs, making them a logical choice for situating such activities. Characteristic in such contexts has been TPACK development through the design and development of instruction using technologies (Angeli and Valanides 2013; Figg and Jaipal 2013; Hofer and Harris 2010), thus validating the need for embedding the authentic work of practicing teachers in teacher education coursework. Although the instructional development was a common theme, nearly every approach was unique.

Angeli and Valanides (2013), for example, engaged candidates in a process called Technology Mapping. According to the authors, technology mapping was a process where technological affordances were discussed, then modeled through content specific design-based learning tasks. Candidates then had the opportunity to apply what was modeled but in a new situation using additional technical affordances as needed. Findings indicated that candidate TPACK did develop, but as the complexity of the affordance increased, the extent to which TPACK developed decreased. This was likely due to the lack of knowledge that candidates have across all the TPACK domains due to their lack of prior teaching experiences (Koehler et al. 2014).

The Technology Mapping approach that Angeli and Valanides (2013) used with candidates can be contrasted with the Learning Activity Type (LATs) approach, which are content based taxonomies of pedagogical approaches with aligned technologies (Hofer and Harris 2010). Hofer and Harris (2010) explained that they engaged preservice teachers in the critical examination of different example lessons constructed using different LATs. This was done to highlight that any of the LATs can be a starting point for lesson creation. Candidates then began creating their own lessons using the LATs with the assistance of a planning guide that prompted candidates to think about key components of effective teaching, such as activating prior learner knowledge. Hofer and Harris explained that using LATs with preservice teachers requires more scaffolding for designing instruction than what in-service teachers typically need. Their five-step process when using LATs with preservice teachers consisted of the following:

1. List learning goals;
2. Describe contextual factors such as learning preference of students;
3. Develop the learning experience by picking multiple LATs and sequencing them in a lesson plan;
4. Design assessments;
5. Determine which aligned technologies from the LATs will be used during the lesson.

In another lesson design-oriented approach to preservice teacher TPACK development, Figg and Jaipal (2013), building off of the LATs, used a process called the TPACK-in-Practice Workshop. In this approach, candidates enrolled in an educational technology course designed professional development experiences for K-12 teachers where they learned how to teach using LATs. Candidates created a four component process where the LAT was modeled by engaging practicing teachers in experiences that required them to use technology tools to achieve a learning target. This was followed by a dialogue about pedagogical considerations within the activity, as well as a demonstration of the tools used in the activity. The final component was a practice task for teachers to create new instruction using what had been modeled. What makes this experience unique is the blended nature of TPACK development. While the TPACK-in-Practice Workshop was a TPACK development approach for in-service teachers, the workshop itself was developed by the preservice teachers, thus developing their knowledge and skills in terms of the relationships between TK, PK, and CK.

Other approaches have been taken in the context of educational technology courses, such as the approach taken by An, Wilder and Lim (2011) where they sought to strike a balance between a fully isolated technology approach and a pure methodological approach, so that no single knowledge domain would be developed in isolation. Kramarski and Michalsky (2010) described an approach grounded in metacognitive support for candidates. Specifically, they used a hypermedia focus where learners could progress through learning opportunities, deciding what they engaged in as they navigated through the environment. Results indicated candidate ability to leverage their TPACK when designing instruction that grew using this approach.

11.2.1.2 Approaches in Content Methodology Courses

Preservice teacher TPACK development has also occurred outside of the educational technology courses. A number of studies (Jang and Chen 2010; Koh and Divaharan 2011; Özgun-Koca et al. 2010) have been conducted in content methodology courses where the traditional focus of such courses has been on PCK development. While lesson planning and implementation were common in these courses as well, modeling the effective uses of instructional technologies was another emergent theme. As was the case with lesson planning in educational technology courses discussed in the preceding paragraphs, modeling techniques used by faculty were unique as well.

Jang and Chen (2010), in a Science and Technology course, used a process called TPCK Comprehension, Observation, Practice, and Reflection (TPACK-COPR), which included learning about instructional approaches, observation of technology-based science instruction, lesson design and implementation, and reflection on implemented instruction. A key characteristic of this approach was the modeling that took place during the course. Experienced science educators modeled effective technology use in the classroom, which according to the authors, was critical because preservice teachers imitated their own uses of technologies with those that were observed. Ertmer and Ottenbreit-Leftwich (2010) stressed the importance of these opportunities, because "although today's students may be fairly knowledgeable about a variety of ICT tools, they have little to no knowledge about how to use these tools to facilitate student learning" (p. 268). Candidates openly recognized the value of the observations and expressed that they developed a deeper understanding of the limitations of certain instructional approaches that used technology to teach science content.

In a similar approach, Koh and Divaharan (2011) used a three-step process called TPACK-Developing Instructional Model. In this approach, faculty modeled different technologies as a way of encouraging candidate acceptance of certain technology tools. Faculty then targeted the development of candidate TCK and TPK providing what Pamuk et al. (2013) described as the necessary framework needed to combine each TPACK domain effectively during instruction. This was accomplished through both additional faculty modeling as well as candidate exploration with the final step being the creation of instruction by candidates. Koh and Divaharan stated that faculty modeling was significant in assisting candidates to develop pedagogical strategies for using technology, which they claimed underscored the importance of modeling when unfamiliar technologies were introduced to candidates.

Modeling was also used in Özgun-Koca et al. (2010) study where an instructor emphasized the technological affordances and how they could be used to create multiple different lessons. Technical affordances were highlighted in the context of pedagogical approaches, in addition to tasks seeking to deepen candidate CK. In conjunction with instructor modeling, candidates developed instruction and implemented it during a field experience embedded in the course.

Redmond and Lock (2013) examined preservice teacher TPACK in a middle level curriculum and pedagogy course where modeling was used. In this course, successful technology integration was modeled, while candidates also participated in a collaborative activity related to diverse and digital classrooms. Topics included contemporary issues such as inclusion and cyber bullying. Results of this study indicated that candidates reported higher levels on all the TPACK constructs except TK and PK.

11.3 Intel Teach Elements in Teacher Development

The Intel Teach Elements (Elements) courses have been used widely in teacher development with as many as 10 million teachers in at least 70 countries (Intel Corporation, n.d.). The Elements courses are freely accessible worldwide making them a potentially valuable resource for both preservice and in-service teacher development. While the use of the Elements as a mechanism for developing teacher knowledge has been widely used, it has not been thoroughly studied and as such there is very little empirical evidence in the literature that characterizes their use. What currently is known about the Elements is the role implementation has in the success in meeting the goals of the program. Light et al. (2006) found that implementation of a unit plan designed during the Intel coursework was a key for success, because it allowed teachers to implement the targeted instructional approaches rather than only learning about the approaches in isolation.

Prior learning experiences, unsurprisingly, were a factor for the degree of success that educators had in using technologies in their practice. Costa and Shand (2010) found that teachers with inclinations to e-learning had increased satisfaction, while those teachers with low technical skills reaped a positive gain in their abilities. This was a finding Light et al. (2006) also discovered where teachers with prior experiences with project-based approaches were able to leverage technologies more widely in their teaching practices.

Teachers have expressed a high level of satisfaction with the Elements, both at the preservice and in-service levels. Todorova and Osburg (2009) found that teachers were satisfied with the use of the Elements course, which they stated, allowed them to collaborate more with other teachers in ways that sustained after the study had ended. Costa and Shand (2010) found faculty perceptions to be positive where faculty indicated that their ability to use technology within the curriculum improved, which is a finding Light et al. (2006) found as well with practicing teachers. Wan et al. (2013) also found teachers to hold favorable perceptions of the Intel Teach Elements and indicated that they would both be more likely to use the new knowledge and skills they developed in their teaching, as well as recommend to others that they take the Intel Teach Elements courses. Additionally, faculty reported that their own development had positive implications for the preparation of their teacher education students (Costa and Shand 2010). As such, faculty reported that they were likely to begin using the Elements in their teacher education courses.

The success educators have experienced in using the Elements that highlight the potential of the courses as an effective educative resource for teachers. This is especially true in the context of an ever more technologically mediated society, where having the appropriate knowledge and skills will be essential for a successful life and career. Yet, Banathy (1993) reminded us that if the educational system is to be impacted, one must look at the systems needed to support change. The quality of each part resides in its relationship to the whole. Preparing preservice teachers by modeling TPACK-based methodology sets the stage for them to implement once they are in the K-12 classroom, another component of the broader educational system.

11.4 Methodology

Using a mixed methodology approach, data was collected over the course of the 2013–2014 academic year at four institutions of higher education throughout the United States. Student surveys, student performance assessments, faculty questionnaires, and course documents were used to examine faculty infusions of Elements modules into their courses and the impact of their use on developing students' TPACK.

A student self-report survey based on the work of Schmidt et al. (2009) provided pretest/posttest data. The survey was modified slightly to broaden content knowledge-related questions to be inclusive of all content areas. These modified questions were aligned with the content area students selected in the demographic section of the instrument. The survey consisted of 33 five-point Likert-type questions aligned to the seven TPACK domains, as well as three multiple-choice questions on the percentage of faculty and cooperating teachers had effectively modeled TPACK. There were also eight demographic questions. Descriptive and inferential statistics were used to analyze student responses.

Performance assessments were used to triangulate survey data. These performance assessments were pretest/posttest lesson plans created by participating students. They were assessed using Harris et al. (2010) TPACK-based technology integration rubric. Descriptive and inferential statistics were used to analyze results.

Faculty participants described their implementation of the Elements course or modules within their teacher education course using an open-ended questionnaire at the end of the study. Data was coded by two researchers who established common themes as a result of analysis. In addition, faculties' course documents were analyzed to identify how the Elements were integrated into the teacher education course.

Participation in the study occurred in two levels. The first level of participation was with 11 higher education faculty from four different institutions: two Midwestern universities and two West coast universities. Five faculties had previously used Element's courses. The second level was that of their teacher education students. There were a total of 239 students enrolled in the courses where 126 completing either the pre- or post-tests, with 86 completing both. The students' majors cut across all levels of K-12 education and 10 content areas. The majority of students were not enrolled in an educational technology major or minor, while about two-thirds had completed a practicum experience in a classroom.

11.5 Intel Teach Elements Selection

Faculty selected five Elements course modules for integration within their teacher education courses. More than one faculty member used three of the Elements course modules.

Table 11.1 Frequency of intel element course implemented by institution

Institution	Project-based approaches	Collaboration in the digital classroom	Designing blended learning	Assessment in 21st century classrooms	Thinking critically with data
1	4	1	–	–	–
2	–	1	–	–	–
3	–	1	3	–	1
4	–	–	–	1	–

Table 11.2 Frequency of modules by course

Intel element course	1 Module	2 Modules	3 Modules	4 Modules	5 Modules
Project-based approaches	–	–	1	1	1
Collaboration in the digital classroom	–	–	–	1	1
Designing blended learning	–	–	–	–	3
Assessment in 21st Century classrooms	–	–	–	–	1
Thinking critically with data	–	1	–	–	–

Notes One faculty member did not report number of modules used

These included project-based approaches, collaboration in the digital classroom, and designing blended learning. Two other Intel Element courses: assessment in twenty-first century classrooms and thinking critically with data, were each used by one faculty member. Table 11.1 summarizes the frequency of faculty that used each of the five Intel Element courses by institution.

Examining the extent to which each Intel Element course was used by faculty found that eight faculties used at least four of the modules, with six faculties using all five. One faculty member did not report the number of modules used, but did indicate that she used two Intel Element courses, project-based approaches and collaboration in the digital classroom. Table 11.2 summarizes the frequency of modules used per course by faculty members.

11.5.1 Intel Teach Elements Integration

Faculty were asked to describe how the Elements course modules that they integrated were offered to their students. Of the 11 courses, six were either blended or completely online, while the remaining five were face-to-face. In the online courses, the use of modules is best characterized as a standalone assignment, much like a textbook or other course readings that the students complete throughout the course. These standalone assignments were typically followed up with discussions. In the fully online courses, the discussions were facilitated asynchronously, while in the blended courses these often occurred during class time. In the face-to-face courses, the implementation of the Elements was similar in terms of being a standalone assignment that students completed with in-class discussion taking place after a module was completed. However, in three of the face-to-face courses, the faculty introduced the content of the Elements to the class. For example, one faculty member completed the first module in class with her students, while another faculty member presented using the materials that accompanied the Elements.

One faculty member, who had no prior experience with the Elements, had a unique implementation of the Elements within course. According to her syllabus, she used the Intel Element course assessment in twenty-first century classrooms, as the foundation for her teacher education course. In the course, students complete three general types of activities: (a) class participation, which included the use of the online learning management system, (b) action plan activities, and (c) a signature course assignment. What makes this implementation of Elements unique is that in all the other courses, the Elements were interwoven as a curricular material, while in this course the Elements course was the bulk of the course rather than a material used with other resources and materials.

While faculty reported that the Elements were standalone assignments, other assignments were often associated with the Intel content. These assignments often were related to lesson planning. One such assignment was an instructional design project that candidates completed at the end of the course that required them to apply the knowledge and skills they had learned throughout the course. Another faculty had students who create a project-based learning unit. Four faculty, who taught different sections of the same course, had students evaluating sample unit plans based on the Intel Element course. Perhaps the most practical assignment that was implemented, related to the Elements course, was the development and implementation of project-based learning lessons by student teachers. A faculty member observed these lessons and discussed results in postimplementation conferences.

When faculty were asked if they would use the Elements again in their course, all of them indicated they would accept the one who was unsure. Even though most faculties would use the modules again, six of the faculty indicated they would modify how they used the modules within their course. The amount of time spent using the Intel modules was a common change mentioned by faculty. One faculty indicated she would "extend the number of lessons" and the duration spent on the Intel content. Another explained that she would spend more time on them and that "it took much more time than I thought for each presentation."

Some faculty indicated they wanted more discussions and collaboration among students the next time they used the Elements. For another faculty, spending more time on project-based learning will be a future priority given the impact she experienced during this study. As she explained, project-based learning had not been a topic of discussion in her seminar in prior semesters. However, as the semester waned and student teachers went on job interviews, "several students were asked about PBL during interviews and they were able to describe the units they taught…were able to talk about their actual teaching and could use the academic language during the interview." She went on to say "PBL was something I never spent much time on before, but will in the future."

While there was a number of faculty who wanted to change how they integrated their use of the Elements, there were four faculty who indicated they would continue to use the Elements as they did during this study. One faculty member offered that she thought the Elements "were a great course!" [emphasis in original]. Another faculty member stated that the course was "appropriately facilitated in this course and would not make any changes," while another faculty member simply explained, "I plan to continue to use Elements."

The faculty member that was unsure of her future use of the Elements indicated they would be a valuable introductory tool when used in conjunction with another project-based learning resource. She explained that she also used a textbook for the course and that in the future she would either need to "drop the book and use INTEL [emphasis in original] in more focus way or keep the book and continue with INTEL [emphasis in original] on an introductory level." She went onto explain that she thought the PBA course was a better fit for practicing teachers. She stated that her "students are pre-service teachers without teaching experience. Many materials were geared towards teachers with an actual classroom, that are interesting [sic] in changing their approach to teaching." The future use of the PBA course for this faculty member is currently unknown beyond a possible introductory role.

11.5.2 Intel Teach Elements and TPACK

To examine preservice teacher TPACK development over the course, paired sample t-tests were conducted on data collected through the Modified Survey of Preservice Teachers' Knowledge of Teaching and Technology. Individual items from the survey were averaged by category and are summarized in Table 11.3.

To triangulate self-report data from the survey, student participant lesson plans were analyzed using the Technology Integration Assessment Rubric (Harris et al. 2010). Pretest/posttest lesson plans were collected from 46 student participants, however, only 27 students submitted two lesson plans that were detailed enough in the content to be taught, the instructional strategies used, and technologies used to allow for assessment. Both researchers independently assessed each lesson plan. Rating scores were then compared with any differences negotiated until agreement was established. In lesson plans prior to the use of the Elements in the teacher education course, students struggled some on each of the four areas measured: (a) supporting curriculum goals with technologies, (b) supporting instructional strategies with technologies, (c) selecting appropriate technologies to use with curriculum goals and instructional strategies, (d) fitting each content, pedagogy, and technology together. Mean scores for each item on the pretest lessons indicated that candidates were approaching appropriate levels for each criterion. A three rating

Table 11.3 Averaged descriptive and inferential results by TPACK domain

TPACK domain	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	P-Value
Technology knowledge	3.794	0.774	4.109	0.759	0.005
Content knowledge	3.961	0.754	4.257	0.609	0.002
Pedagogical knowledge	3.729	0.825	4.251	0.665	<0.001
Pedagogical content knowledge	3.679	0.779	4.14	0.643	<0.001
Technological content knowledge	3.605	0.801	4.17	0.617	<0.001
Technological pedagogical knowledge	3.888	0.736	4.326	0.621	<0.001
Technological pedagogical content knowledge	3.705	0.771	4.236	0.644	<0.001
Models of TPACK by Faculty/K-12 teachers	3.628	0.861	4.012	0.756	0.002
Models of TPACK by Faculty/K-12 teachers (Rating Scale)	2.711	0.988	2.917	0.925	0.097

Notes $p < 0.05$ indicates statistical significance, $N = 86$

would indicate appropriate alignment, support, or fit on each item. Table 11.4 provides an overview of pretest and posttest descriptive and inferential statistics.

Lesson plans created after the use of the Intel modules were assessed using the same rubric developed by Harris et al. (2010). Students fared better on each criteria indicating that students were able to align, support, and fit technologies with curriculum goals, instructional strategies, and all together. To determine if these increases were statistically significant, a paired sample t-test was used with significance level of less than or equal to 0.05. The results indicated that on each of the four criteria that the growth in mean scores was statistically significant.

Table 11.4 Pretest/posttest lesson plan descriptive and inferential results

TPACK domain	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	P-Value
Curriculum goals & technologies (TCK)	2.960	1.241	3.560	0.712	0.01
Instructional strategies & technologies (TPK)	2.760	1.128	3.560	0.651	0.002
Technology selection(s) (Compatibility with curriculum goals & instructional strategies)	2.760	1.128	3.480	0.770	0.002
"Fit" (Content, pedagogy, and technology together)	2.800	1.190	3.480	0.770	0.004

Notes $p < 0.05$ indicates statistical significance, $N = 27$

11.6 Discussion

Teacher education programs are a significant part of the K-12 education system. Preparing preservice teachers to enter the K-12 classroom ready to create TPACK-based learning experiences and with the understanding of the role of resources, such as the Intel Element's courses can provide, empowers these future teachers with the knowledge and skills to impact their students' growth around twenty-first century skills. It is worth noting that the preservice teacher's growth happened at significant levels and further exploration of the nature of this growth to determine if it is limited to the use of the Elements or if other factors, either in conjunction or independently of the Elements, exist that is having an effect of preservice teacher TPACK development.

Faculty used a variety of Elements course modules in their teacher education courses. The three Elements courses most used, Project-Based Approaches, Collaboration in the Digital Classroom, and Designing Blended Learning, align well with ongoing discussions of twenty-first century learning. The extent to which faculty used the Intel Element course modules in their courses was also interesting. Over three-fourths of the faculty chose to use the bulk of each of the Elements course modules. While it is true some faculty had the opportunity to previously use the Elements, the fact that there were faculty who, with their first experiences using these resources, decided to use the majority of the course modules highlights the potential value of these as resources within teacher education. Certainly faculty identified the value of the Elements; however, their value may depend on how these resources are implemented within the course.

Of particular note was that the fact that a majority of faculty planned on using the Elements again, although about half of the faculty wanted to change how they implemented them within their course. While these faculty recognized the value of the Intel Element content within their course, they looked to future semesters and how their curriculum might change in an effort to improve teaching and learning using this resource. Many of the changes faculty planned pointed towards deeper integration either through more time or more collaboration among students. The implication of this deeper interweaving is that faculty considering the use of these courses may need to reflect on the long term impact their decision will have on their course, planning, and the type of supports they may need to leverage the Elements as they prepare their students with the skills needed in the high tech, networked society in which they will live.

11.6.1 Limitations

As with any study, there are certain limitations that reduce the extent to which findings can be generalized. The robustness of this study was reduced due to the low response rates within a number of the different courses participating in the study, thus preventing the use of inferential statistics by course. To strengthen the statistical power of the study, data from all courses were combined allowing for the analysis of mean differences, but by doing so, possible significant differences that may exist between different courses, which would impact the findings, were not identified. Future studies should seek to increase response rates to allow for the use of inferential statistics within individual courses, which would ultimately better represent the population and allow for greater generalizations. In doing so, any significant differences that do exist between courses can be identified and each course can be analyzed for mean differences independently. Appendix C provides a summary of descriptive statistics by course for the Modified Survey of Preservice Teacher Knowledge of Teaching and Technology.

In addition, the Modified Survey of Preservice Teacher Knowledge of Teaching and Technology is a self-report instrument. As such, it is possible that participants responded in ways they felt they needed to respond, thus reducing the validity of these assessment points. Although survey analysis was triangulated with performance data, due to the small overall sample size of both pretest/posttest survey and performance assessment, the researchers suggest further studies be conducted to corroborate the findings of this study. Specifically with performance data that is less susceptible to participant threats to validity.

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Chapter 12
Using Two Frameworks to Promote E-Leadership and Teacher Development

David A. Slykhuis and John K. Lee

Abstract Working in partnership with Microsoft, a team of university faculty created the Technology Enriched Instruction (TEI) professional development workshop to promote the effective use of technology in the classroom. This workshop was originally aimed at teacher educators in an effort to support best practices based on theory and research about using technology in teaching. After piloting, the TEI workshop was extended to meet the needs of all higher education faculty. Two conceptual frameworks form the cornerstone of the workshop: TPACK and 21CLD. These frameworks provide the intellectual and practical grounding for all workshop activities. This chapter explores the application of TPACK and 21CLD as well as the decision-making behind and implications for expanding the focus of TEI.

Keywords Professional development · TPACK · 21CLD

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12.1 Technology in Teaching

Over the past decade, Microsoft has invested over a half a billion dollars helping to train teachers around the world in the appropriate and effective use of technology in education through the Partners in Learning Program (PiL). Through its Microsoft Educator Network, PiL supports a worldwide community of millions of educators and provides them a platform to share best practices and to be a part of a global educator community. In 2011, senior leadership at Microsoft decided to expand the reach of Partners in Learning to Higher Education.

Given Microsoft's experience in K-12 education, the initial focus for this new effort in higher education targeted faculty in schools and colleges of education as this provided a close bridge to the K-12 work of PiL. The logic of a teacher education focus was that by working directly with teacher educators, preservice teachers would be better prepared to integrate technology into their classrooms as they began their teaching careers, thereby having a long-term multiplying effect.

12.1.1 The Teacher Education Initiative

In its initial form, the Teacher Education Initiative (TEI) focused on teacher education faculty. The TEI leadership team concluded that the biggest impact on K-12 teaching and learning could be made by focusing on changing the technology practices of teacher education faculty. TEI also focused on academic disciplines. This decision was guided by the workshop developers' decision to use the Technological and Pedagogical Content Knowledge (TPACK) framework as the theoretical grounding for the workshop and as an anchor for creating workshop activities. The TPACK framework is a model for describing how teachers reason through the process of integrating technology into their teaching. Building from the work of Shulman (1986), Mishra and Koehler (2006) developed the TPACK model by arguing that technology integration in teaching and learning requires "a thoughtful interweaving of all three key sources of knowledge: technology, pedagogy, and content" (p. 1029). TPACK establishes a way for teachers to reason through the decision-making process for using technology.

In the *Handbook of Technological Pedagogical Content Knowledge (TPCK) for Educators,* Koehler and Mishra (2008) specifically address the unique needs that teachers have when using existing technology by arguing that adaptation by teachers of "general-purpose tools created for the world of business (e.g., spreadsheet programs) to the classroom context requires working through this opacity (and our functional fixedness) to reconfigure and repurpose these existing technologies for pedagogical purposes" (p. 8). Instead of teachers making didactic use of technology tools such as those available in Microsoft Office, the TPACK framework suggests a reasoning process that puts the pedagogical and content needs of teachers and learners in dynamic tension with the affordances of the tools.

With the TPACK framework in mind, the initial TEI workshop was designed around the following outline:

- Introduction to the TPACK framework
- Introduction of specific technology skills and tools
- Concurrent discipline-specific sessions focused on content and pedagogy.

In this format, the majority of the time was actually spent in the concurrent discipline-specific sessions focused on English/language arts, mathematics, science, and social studies.

The first TEI workshops were delivered in this format in 2012, in Austin, TX, Chapel Hill, NC, and Washington, DC. With each of these workshops there were some successes and some challenges. A significant challenge proved to be filling the workshops with content-specific teacher education faculty. The pool of teacher educators targeted for the workshop was limited to those teaching content pedagogy or teaching methods classes. We found that many of the faculty attended these first three workshops were outside of our targeted population, but they still found merit and value in the workshop.

One of the real success stories of these early workshops was the incorporation of the TPACK framework. Facilitators and participants quickly gravitated to this framework and were able to see how it applied to their teaching. Leading the day off with the TPACK framework, and then focusing the work in content groups, technologies could be introduced in ways that were specific to the disciplines. It was productive for faculty to see work through the individual domains of technology, pedagogy, and content knowledge.

However, the focus on teacher educators meant that TEI remained two steps removed from the classroom. Under the original TEI model, TEI facilitators worked with teacher education faculty who worked with preservice teachers who worked with K-12 students. The TEI leadership team desired a more direct impact on student learning. Thus, a decision was made to shift to a P-16 model of education (Chamberlin and Plucker 2008) and focus on general college and university faculty instead of teacher educators.

12.2 Technology Enriched Instruction

The TEI leadership team began to explore the general demand for technology-related professional development in higher education. Calls for technology adoption, integration, and enhancement in higher education have been in place for some time now (Becker et al. 2015). Kukulska-Hulme (2012) outlines a position on faculty development which suggests, “faculty engagement should go beyond technology adoption in their teaching to adoption in their own professional learning” (p. 248). The TEI program was well positioned to deliver this approach to preparing higher education faulty for using technology. At the same time, Microsoft

Partners in Learning was receiving increasing interest in higher education professional development from around the world.

In order to address the growing need for TEI in higher education and for an expanded global focus, the TEI leadership team began a redevelopment process. The TPACK framework had been used successfully in cross-disciplinary higher education professional development programs (Stover and Veres 2013) as well as in short-term face-to-face and blended situations (Alsofyani et al. 2012). This yielded a newly framed TEI program, rebranded as Technology Enriched Instruction, refocused on general faculty in higher education, and repositioned as a global program. Dropping the emphasis on teacher education was an important material change in direction for the program, but a second and perhaps equally important shift was to move toward a technology "enrichment" approach. These changes allowed the TEI leadership team and facilitators to focus on solving real problems and to consider how technology can make teaching and learning more productive.

12.2.1 From Frameworks to Workshop

Global economic, political, and technological changes are creating new environments in which to teach and learn. Knowledge of twenty-first century skills and the technology that addresses these skills can lead faculty to change practice towards a more student-centered model (Archambault et al. 2010). The newly designed TEI workshop was designed to address these changes. The TEI leadership team decided to address these changing conditions by adding twenty-first Century Learning Design (21CLD) as a second framework.

With the TPACK and the 21CLD frameworks in mind, the TEI leadership team worked to construct a workshop to help college faculty in all content areas be more mindful of the their uses of technology in the classroom. This new Technology Enriched Instruction quickly evolved to include eight activities (Table 12.1). The workshop was designed to introduce a limited number of thoughtfully selected technology tools used throughout the workshop as a model for how technology can enrich instruction. During the workshop, participants are provided opportunities to practice using these technologies as they examine the TPACK and 21CLD frameworks and consider their own teaching practices.

Table 12.1 Technology tools used in the TEI workshop

Technology	Level of use	Use in TEI
OneNote	Personal	Taking notes during the workshop
Padlet	Collaborative	Sharing emerging ideas from activities during the workshop
Yammer	Community building	Expanding communication with others in the workshop and educators in the larger Yammer TEI network

One important aspect of the workshop is the method of delivery. The workshop is facilitated by a pair of leaders, but the amount of direct instruction is deliberately limited. The goal of the workshop is to have faculty examine their own practice, and lead them changing their practice. In order to meet this goal, in each segment of the day, the topic is introduced then and faculty are given a task or activity involving the topic, they then debrief and discuss in small groups. Only then do the facilitators lead a large group discussion to ensure the content of the activity was correctly conveyed and to lead into the next activity.

The day begins by providing participants with an early opportunity to use technology in an authentic way. The activity features the use of an Excel survey to collect information from participants about their existing uses of technology. In addition, the two conceptual frameworks (21CLD and TPACK) are introduced and perhaps most importantly participants are introduced to an inquiry model that is used to support participants as they examine their own instructional practices and consider how they might enrich their teaching using technology (see Fig. 12.1). Work with this inquiry model is woven into all of the workshop activities to encourage faculty to begin to think about their own teaching practice from the very beginning.

The second activity introduces three additional technology tools that are used throughout the workshop as well as the different purposes for each tool (Table 12.1). The tools represent three levels of instructional technology use from

Fig. 12.1 Inquiry Model used to Promote Technology Enhanced Instruction

personal uses of technology (OneNote) to collaborative uses (Padlet) to community building (Yammer).

The third and fourth activities in the workshop establish the context for the workshop. In the third activity, the faculty are prompted to consider how today's students are different than the students who came a generation before them and how the learning expectations of these students necessitates new practices among faculty (Bull 2010; Koehler and Mishra 2009). Faculty are then asked to consider skills appropriate for the twenty-first century learner versus those skills relevant for the twentieth century learner. Differences and similarities are explored and discussed using Padlet and Yammer.

With the context for using technology to enhance established teaching, the focus of TEI shifts to the two theoretical frameworks framing the workshop, 21 Century Learning Design (21CLD) and Technological Pedagogical Content Knowledge (TPACK). These two are introduced to help faculty broaden their thinking about how technology can support student learning. As discussion about 21CLD and TPACK expands, faculty are encouraged to make connections to their content areas and the courses they teach, specifically focusing on the instructional problem or opportunity they previously identified as part of the ongoing inquiry. To facilitate discussion about 21CLD and TPACK, faculty use all three technology tools to make connections between their instructional practices and those of their peers.

The two frameworks begin to crystallize for participants in the fifth activity–the TPACK game. The game is based on the version originally developed by Judi Harris, Punya Mishra, and Matt Koehler for the 2007 National Technology Leadership Summit (Richardson 2010). The TEI version of the TPACK game features three sets of playing cards: blank content topic cards, pedagogy cards with different pedagogical strategies on each card (e.g., group discussion, simulation, presentation), and cards with different technology options on each card (e.g., word processing, videoconferencing, data analysis, etc.). Through a series of three increasingly complex rounds, participants reason through a process of finding a "fit" between a content topic they have identified from their own practice and one or more of the pedagogies and technologies listed on the cards. This activity leads to robust discussions about the optimal combinations of content, pedagogy, and technology. In the process of playing this game, participants begin to formulate ideas for the instructional design activity that follows.

After exploring the changing nature of teaching and learning and the 21CLD and TPACK frameworks, faculty are challenged to redesign an activity from one of their courses drawing on what they have learned in the workshop. Participants have an extended time period to plan individually or collaboratively to complete their redesign. Participants use the 21CLD rubrics and cards from the TPACK game as they revise their activity and include information about the course topic, learning goals, pedagogical strategies, and technologies, if present, in their original approach as well as their redesigned vision for each of these elements of the activity. The participants' work, along with all workshop materials, is posted on the TEI Yammer network allowing easy and ongoing access for faculty around the world. Participants also share their revised lessons in small groups, discussing how 21CLD and TPACK are represented in their designs. As a final activity, groups identify one revised activity from their group that they agree best exemplifies 21CLD and TPACK to share with the larger group. They are encouraged to use a creative technology tool to share the revised activity. This process of sharing both affirms the faculty who created the activity and provides additional ideas and approaches for the other participants to consider. Finally, the small groups share their key findings in the workshop's Yammer group. In this way, they are able to extend the conversation beyond the confines of the workshop.

During the wrap-up the facilitators share how the TPACK and 21CLD frameworks were used in the development of the workshop. The TEI leaders carefully considered the technology, pedagogy, and content (TPACK) choices focusing on making the best fit between all three areas. Perhaps surprisingly given the sponsorship from Microsoft, the conversations began around the content and not the technology. The content was to have each faculty member leave with an increased knowledge of how to use TPACK in planning their instruction and how to increase the twenty-first century skill development in their students. With those content goals in mind, the next decision was to determine the appropriate pedagogy for the workshop would revolve around inquiry. The workshop was meant to contain minimal lecture about technology. Instead, faculty were to experience the technology and to discover the different challenges and affordances each has to offer. Lastly, there were the considerations of what technology that would fit with the TPACK and twenty-first century skill content and inquiry pedagogy. Technologies such as Padlet, Yammer, OneNote, and Excel all fit well with the content and pedagogy.

The workshop was also meant to increase faculty member's twenty-first century skills. Tools such as Yammer and Padlet would increase areas of 21CLD such as communication, collaboration, and knowledge construction. By using them in conjunction, collaboration should measure at least a level three on the 21CLD rubric, with faculty making substantive decisions together, not only at a small group level, but with shared knowledge from the larger group.

The differences between the previous Teacher Education Initiative and the current Technology Enriched Instruction workshop are significant. The new TEI uses two powerful conceptual frameworks, 21CLD and TPACK, to challenge college faculty to rethink how they teach. TEI is now able to more directly impact student learning. Rather than simply giving faculty the information they might need to accomplish a particular task, the participants are challenged to immediately apply what they are learning. These intentional changes in the design and implementation of the workshop operationalize the tight "fit" TEI encourages between the content, pedagogy, and technology—exactly what is encouraged of participants. The results have been dramatic and positive. While TEI workshops had always received high evaluations, the atmosphere in the revised workshops is even more encouraging.

12.3 The Future of the TEI Project

TEI has evolved to address an important need in higher education. TEI workshops have been conducted around the world with events in Stockholm, Sweden; Seattle, USA; Sharjah, UAE; Budapest, Hungry; Wuhan, China; Jakarta, Indonesia; Kiev, Ukraine; Niagara Falls, Canada; Alberta, Canada; Atlanta, USA; Williamsburg, USA, Doha, Qatar; Sydney, Australia; Gaborone, Botswana; Johannesburg, South Africa; New Delhi, India, Chiang Mai, Thailand, Seoul, South Korea, and Monterrey, Mexico. Faculty who have competed the workshop have conducted their own workshop in places such as Vietnam, Brunei, Malaysia, Egypt, Lebanon, Russia, Poland, and Norway (Fig. 12.2).

The TEI program is designed to provide higher education faculty with practical experiences to support their growth in understanding about how to enhance their teaching with technology. The future of the project hinges on three design and development questions.

1. How can TEI be scaled to obtain a maximum global impact?
2. What technology platforms and instructional designs will best support the scaling of TEI?
3. How can the TEI network be sustained and nurtured over time?

Each of these challenges is explored below given 21CLD and TPACK frameworks, related literature, and broader considerations for faculty development.

12.3.1 Scaling TEI

One of the most difficult issues for growth-oriented professional development programs is the question of how the program can be expanded while maintaining

Fig. 12.2 The TEI global footprint

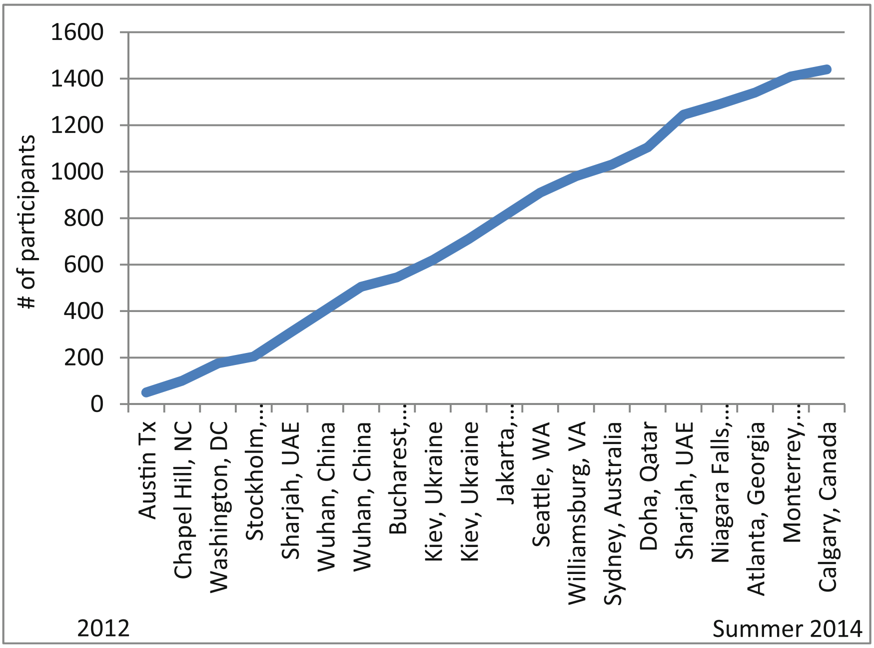

Fig. 12.3 Cumulative number of participants over the history of TEI

quality. TEI has expanded dramatically in the 2 years of its existence, growing from a teacher education professional development program in the United States to a global program delivered to higher education faculty in all content and professional areas (Fig 12.3).

While the program has grown, TEI has considerable untapped potential going forward. The growth trajectory of TEI has the possibility for near-term exponential expansion. Figure 12.4 represents growth in TEI projected at the current rate over a 5-year period.

Of course, with such expansion come growing pains. TEI has encountered a dilemma faced by many professional development programs that have identified untapped demand for their program. The question facing the TEI program is how to grow smart, while maintaining the design features that have made the program successful.

One method for expanding the TEI program to meet growth projections is a train the trainer (TTT) model. The TTT model is a commonly accepted means by which to expand the reach of educational initiatives when existing models for delivery are inadequate (Besculides et al. 2012; Pearce et al. 2012; Suhrheinrich 2011). Using a TTT approach, TEI core facilitators can prepare local facilitators to replicate the TEI program with full fidelity to the design of TEI and with strategic support from the TEI core facilitators.

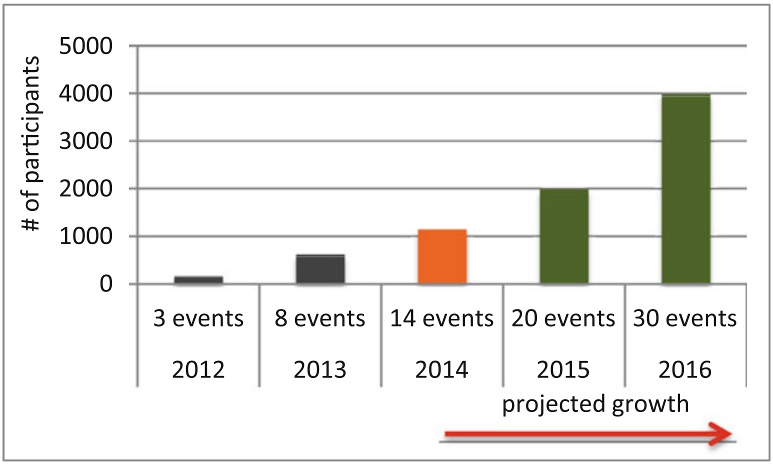

Fig. 12.4 Projected growth in TEI

By bringing on local facilitators through a TTT program, TEI workshop offerings can expand at a rate that will outpace the more closely managed program in place now. How to manage this expansion has become a central concern of the TEI leadership team. The TEI program has begun implementing a TTT program with an initial trainer event in the United Arab Emirates and will continue to explore this model for increasing the capacity of TEI to reach more faculty around the world.

12.3.2 TEI Platform

In the initial phases of TEI, the program utilized a blended platform drawing on both face-to-face and online elements. While this blended approach has been important to maintain, it is far from an even split. In fact, the bulk of the TEI workshop program has been delivered face-to-face (Fig. 12.5).

The design of online activities in TEI face-to-face workshops sought to provide participants with an experience using online technology tools as a way to extend the experience of participants. During the TEI workshop, participants are provided with opportunities to collaborate across the physical constraints of the room. For example, in the larger workshops, groups on one side of the room are able to gain access to knowledge and feedback from participants on the other side of the room using online tools like Yammer and Padlet when they otherwise would not have this opportunity. This online interaction within the room has enabled TEI facilitators to leverage and distribute expertise while also enhancing interaction among participants. As TEI grows, the amount of face-to-face delivery is expected to diminish as new platforms for delivering the workshop are developed.

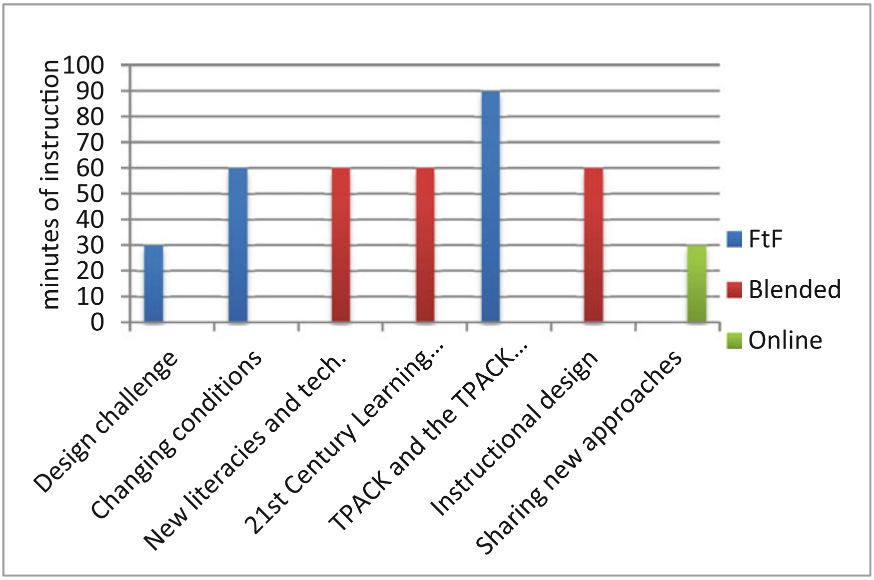

Fig. 12.5 Face-to-face, blended, and online activities

12.3.3 TEI Network

The Yammer online social network has successfully been used to extend workshop activities and model best practices for TEI participants. In addition to using the tool to facilitate discussion among participants during the workshop, some participants have continued the conversation and collaboration beyond the workshop.

The TEI program made an intentional investment in the Yammer networking system. With over 3300 members in the TEI Yammer network, the platform has provided TEI with an avenue for encouraging interaction among TEI participants (see Fig. 12.6 for a snapshot of TEI Yammer usage statistics).

Major elements of the TEI program are intertwined with the Yammer network. Participants are contacted before the workshop to create an account and begin to engage workshop materials. During the workshop, the Yammer network is used to facilitate synchronous online discussion and the sharing of resources. The Yammer tool allows facilitators to interact in an environment that can be contained to small groups or individual workshops, while also holding the capacity to be integrated across the entirety of the TEI project.

To date, the use of the Yammer network after workshops has been limited to information sharing and occasional organic interchanges among those who have completed the program. The development of a more robust post-workshop TEI network will require reconsideration for how and when Yammer is being used. Yammer has been used to support synchronous workshop activities, but has a much stronger potential as a tool to support the development of an extended

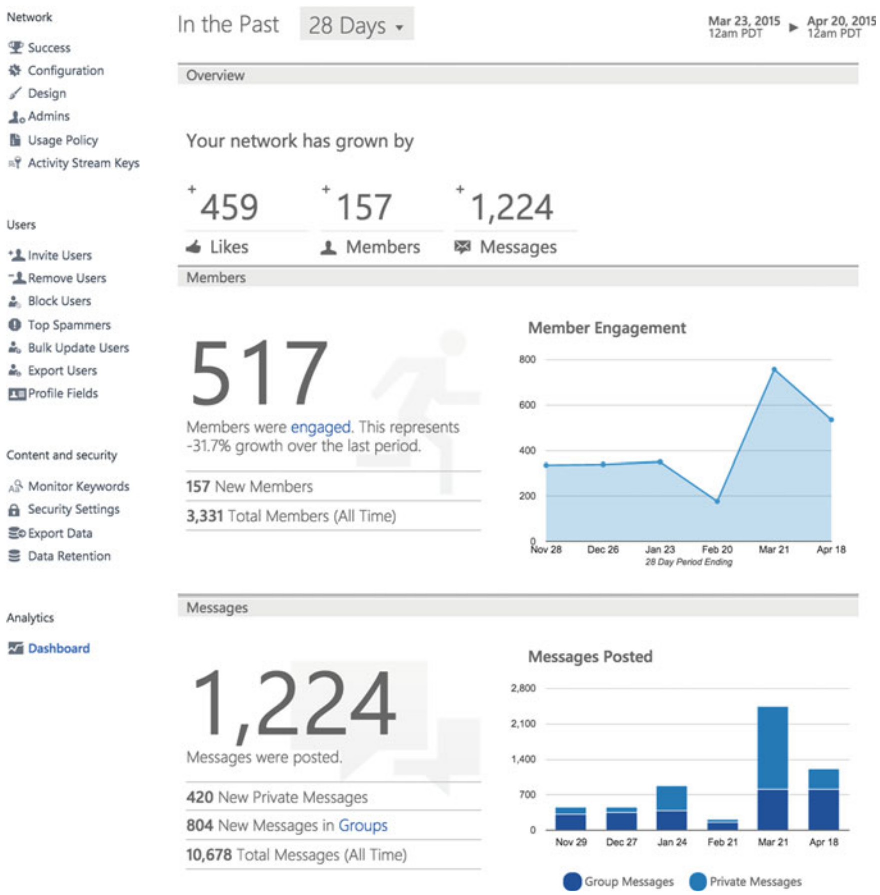

Fig. 12.6 Snapshot of TEI usage statistics

TEI asynchronous network. While faculty are beginning to use social networking tools (Moran et al. 2011), their use lags far behind students' uses of social networking (Roblyer et al. 2010). The TEI program seeks to push the envelope and encourage faculty to use social networks to do things that are not possible in other environments.

12.4 Preparing TEI Leaders

The continued expansion of TEI required the training of additional faculty leaders to deliver TEI workshops. Initially, these faculty members were drawn from the pool of faculty who were part of the Teacher Education Initiative or from contacts within the Society of Information Technology and Teacher Education (SITE). To prepare these faculty members to become TEI leaders, a series of webinars were developed and delivered. These webinars focused on the workshop activities and the pedagogies to be modeled at the workshops. However, even with these additional TEI leaders to conduct the workshops around the world, it was still difficult to effectively scale TEI to reach the number of faculty targeted.

Making the workshop materials open source encouraged a proliferation of the workshop ideas and concepts. Both the TEI participant and instructor workshop manuals are available as open source documents, licensed under Creative Commons Attribute and Share Non-Commercial. Faculty who successfully complete the workshop are encouraged to take these materials back to their institutions and regions and to present TEI workshops to their colleagues.

This has resulted in a number of organic TEI workshops, particularly in two places, the UAE and in Southeast Asia. In the UAE, these TEI workshops were seeded in a more purposeful format using the TTT model alluded to earlier. After presenting the TEI workshop to over 100 faculty members from around the UAE, about 20 faculty attended a train the trainer workshop the following day. During this train the trainer experience the faculty members were exposed in much greater detail to the design process and rationale behind the experience they went through the day before to become TEI leaders. In addition, they were taught the mechanics of the day, how to use the technologies in the presentation, and how to keep the focus on participant inquiry and away from a lecture model. Many of these participants went on to lead smaller scale TEI workshops throughout the UAE. One presenter even led a TEI workshop at regional conference in Saudi Arabia. For some of the initial TEI workshops offered additional support was provided from a distance, however, these scaffolding mechanisms have now been removed and they are operating independently.

The expansion of TEI in Southeast Asia happened in a more organic fashion. The impetuous for this expansion was a TEI workshop in Jakarta, Indonesia that was attended by over 100 faculty. These faculty members were then encouraged at the conclusion of the workshop to take TEI materials and to replicate the workshop and the faculty latched on to this idea vigorously. Without the train the trainer experience or direct support from TEI facilitators, numerous TEI workshops have been conducted in this region. Several of the faculty who presented these additional workshops also attended a second, abbreviated TEI workshop conducted in Chiang Mai, Thailand in conjunction with a UNESCO regional summit for resource and training distribution centers. They were excited to share their experiences and successes.

More recently additional TEI leaders were trained at a workshop at the 2015 SITE conference in Las Vegas, NV. The faculty members attending this workshop are part of a new network of TEI leaders positioned to be responsive to regional demand for TEI workshops.

12.4.1 Yammer as an ICT Tool for Facilitating Leadership

One of the most important tools for facilitating leadership within TEI has been Yammer. Faculty members have used the Yammer platform to create groups, work together, and to stay in contact with each other. With over 3300 members, the TEI Yammer network has achieved the critical mass of faculty members need to spark and sustain independent faculty activity. Yammer has become an active, vibrant community on its own. A working group for each of the 29 face-to-face TEI workshop conducted to date was created in the TEI Yammer network. There are, however, a total of 279 groups active in the TEI Yammer network. In those groups, 10,678 messages have been sent either to groups or to individual members and 2423 files have been shared.

12.5 Taking TEI Online

The face-to-face workshops have achieved the goal of delivering support for faculty interested in enriching their uses of technology. The reach of TEI, however, has been limited due to travel and cost restraints. In order to overcome these barriers, an online version of the workshop has been created. Due to the nature of the face-to-face TEI workshop as being heavily dependent on faculty inquiry, the online version is scaled back in terms of the depth, but aims to support and encourage new types of interaction not possible in face-to-face settings.

The online course was created using Microsoft Office Mix, a tool that allows for the recording of video files embedded into a PowerPoint presentation. The content is divided into five online modules:

1. Introduction
2. Changing Conditions of Teaching and Learning
3. 21CLD
4. TPACK
5. Instructional Design.

While these modules mirror the design of the face-to-face workshop, they serve more as an introduction to the topics than a deep dive into the content. They provide support for faculty to examine the 21CLD and TPACK frameworks and to examine their own instructional practices.

Each module contains interactive activities to support faculty as they consider the two frameworks and their instructional practices, with most of these activities being delivered through the Yammer TEI network. Working in specially designated Yammer groups for the online TEI, faculty members interact with other faculty as they share the experience of completing the online course with peers from across the world.

12.6 Conclusion

The TEI program provides faculty with two conceptual frameworks to support them in making sound instructional decisions when using technology to enrich their teaching practice. The TPACK framework allows faculty to consider the content they are teaching, the pedagogies they use to teach that content, and the technologies they can use to enhance their teaching. When faculty use the TAPCK framework to guide their instructional reasoning, they will reduce the likelihood of technologies being chosen simply because they are the latest and the greatest available. The 21CLD framework provides faculty with detailed rubrics allowing them to reflect on their own teaching practices. These rubrics help faculty to select technologies and methods of instruction by focusing on students' needs in preparation for today's workplace. By bundling TPACK and 21CLD in a faculty-centered and inquiry-based workshop, thousands of faculty members have already enriched their instruction with technology. In turn, tens of thousands of students have benefitted from experiencing these improved classrooms.

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Chapter 13
E-Leadership and Teacher Development Using ICT

Punya Mishra, Danah Henriksen, Liz Owens Boltz and Carmen Richardson

Abstract In this chapter, we develop a definition of e-leadership that extends from the business sector to encompass educational contexts. We describe schools as complex ecologies and dynamic organizations that require a change in both traditional forms of leadership and more recent ICT use. We use the RAT (Replace, Amplify, Transform) framework to explain the varying degrees to which ICT has been used in business and education and relate this model to the research in e-leadership. It is through the purposeful, transformational use of ICT and the meaningful development of multiple kinds of knowledge that those in charge of teacher education and growth can use ICT to develop a new kind of teacher leader.

Keywords E-Leadership · Leadership · Teacher development · ICT · Teacher education school ecology · Systems change · Technology integration

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13.1 E-Leadership and Teacher Development Using ICT

Internet and Communication Technologies (ICTs) have transformed many aspects of the way we work and live today. It has been argued that the integration of new technological tools has the potential to change how organizations function and the nature of leadership required in these changing settings. Schools as knowledge industries are often seen as being an important context for such changes. In this chapter, we explore the idea of e-leadership within the context of schools and teacher development.

We begin by outlining the overall structure of the argument we present. Following a brief introduction and overview of existing work on e-leadership (much of which has been in the domain of business), we develop a definition of e-leadership that would apply to educational contexts as well. We note that current work on organizations has indicated that the effects of technology upon organizations is not determined by the technology itself, but rather that it occurs within a reciprocal relationship between the technology and the organization (in terms of its culture, structure, approach, context and more). To better understand this nonlinear, nondeterministic, and reciprocal process of technology infusion, we offer the metaphor of organizations as complex ecologies. This perspective on organizations allows us to work with three different ways in which technology can influence and change leadership—via replacement, amplification, and transformation. The Replacement, Amplification, and Transformation (or RAT) model has been utilized in terms of technology integration in classrooms in the past, and we suggest it can apply to models of e-leadership. We explain each of these components and provide examples from the world of business and education. Finally, we investigate the consequences of this approach for teacher education and teacher professional development.

13.1.1 Introduction

Early works on e-leadership, often originating from the business and management sphere, tended to paint the rapid rise of technology-enabled work environments in rosy colors. Technology, as these works would have it, could offer institutions a veritable panacea for workplace challenges: Employees from all over the world would be able to communicate, collaborate, and telecommute. Productivity would soar, and complex tasks would soon be completed with astonishing efficiency. Leaders would be able to effortlessly monitor the status of employees and their projects. Yet accompanying these sanguine visions of the future were calls for a more critical examination of the relationship between leadership and technology.

Today, there seems to be general agreement in the literature that established perspectives on leadership (such as authentic leadership, transformational leadership, and servant leadership) still offer value and relevance. In other words, the introduction of ICT into an organization and its work practices can lead to changes, but the processes are not as linear and the effects are not as deterministic as described in some of the literature. For example, it is well established that leaders play a crucial role in team performance by modeling teamwork and setting expectations (Cascio and Shurygailo 2003). However, traditional approaches do not necessarily or automatically transfer to newer, technology-enabled environments (Gurr 2006; Kahai and Avolio 2004). So long-established theories of leadership may be necessary, but not sufficient, for successful leadership in ICT-mediated environments.

Avolio et al. (2014) see a transformational potential in what technology can do to and for human society, but believe that our understanding of how technology is implemented in organizations and the impact on how people collaborate and work is limited because the topic has not been explored fully. Avolio et al. (2000) argued that ICT creates a new context for leadership that results in a co-evolution of technology and leadership—these two components work together, influence each other, and are connected within the organizational context. Technology, they argue, is changing organizations and the very definition of leadership (Avolio et al. 2014). Gurr (2004) came to the same conclusion, stating that ICT and leadership have a reciprocal relationship with each impacting the other as change occurs.

One of the challenges of thinking about e-leadership in education is that a significant portion of the literature on the topic has focused on business or corporate settings, with relatively little attention paid to what these ideas mean for schools and other educational contexts. This is not to say that these ideas of e-leadership do not have implications for education and teachers, but that the contexts are different, the existing literature is limited, and we need to be careful in how these ideas are conceptualized, based on context. In the next section, we provide a definition of e-leadership that is broad enough for both business/management as well as educational contexts.

13.2 Defining E-Leadership

Starting from a business and management perspective, Avolio et al. (2000) defined e-leadership as a social influence process mediated by technology (which they refer to as Advanced Information Technology, or AIT):

> E-leadership is defined as a social influence process mediated by AIT to produce a change in attitudes, feelings, thinking, behavior, and/or performance with individuals, groups, and/or organizations. E-leadership can occur at any hierarchical level in an organization and can involve one-to-one and one-to-many interactions within and across large units and organizations. It may be associated with one individual or shared by several individuals as its locus changes over time (Avolio et al. 2000, p. 617).

Kahai and Avolio (2004) modified this definition slightly, referring to information technology in a more general sense and elaborating on the social, cognitive, and behavioral ramifications of leadership:

> In this entry, e-leadership is defined as a process of social influence that takes place in an organizational context where a significant amount of work, including communication, is supported by IT. That process of social influence is aimed at producing a change in attitudes, emotions, thinking, behavior, or performance (p. 418).

More recently, Avolio et al. (2014) offered an updated definition that reaches beyond the field of business and describes e-leadership as "a social influence process embedded in both proximal and distal contexts mediated by AIT that can produce a change in attitudes, feelings, thinking, behavior, and performance" (p. 107). The broadness of this definition lends itself to educational settings as well.

Conceptualizing e-leadership as a "social influence process" emphasizes the social elements of any organization. In other words, ICTs are an important component of e-leadership but are situated within the larger social context of the organization—a social context that can also relate to how any leadership is approached and enacted. Again, we see that the relationship between an organizational context, and the different elements of leadership and technology within that organization, are complex and interconnected. They are affected by each other and by aspects of the organization as a whole.

We suggest then, that one of the important challenges to understand in this regard is that organizations are complex and the effects of new technologies are not necessarily predetermined. The culture of the organization can often distort, undermine, enhance, or otherwise affect the role of technology. As Kentaro Toyama (2015) in his recent book *Geek Heresy* suggests, technology often acts as an amplifier of social conditions—having the potential to enhance both the positive *and* the negative. Thus, if we have to develop a nuanced understanding of the role of ICT and leadership in educational settings, we need a new way of thinking about organizations and organizational change and leadership.

13.2.1 Rethinking Organizations and Their Metaphors

There are various metaphors that we can use to think about organizations. Metaphors do not just shape our communication, they also shape the way we think and act (Lakoff and Johnson 1980). As Gareth Morgan (1997) writes in his book *Images of Organization,*

> All theories of organization and management are based on implicit images or metaphors that persuade us to see, understand, and imagine situations in partial ways. Metaphors create insight. But they also distort. They have strengths. But they also have limitations. In creating ways of seeing, they create ways of *not* seeing. Hence there can be no single theory or metaphor that gives us an all-purpose point of view. There can be no "correct theory" for structuring everything we do (Morgan 1997, p. 348).

For instance, viewing an organization as being akin to a *machine* provides certain ways of thinking about the role of individuals and leaders within the organization. It is not surprising, given the ubiquitous nature of this metaphor, that when things are going well, we speak of organizations that "run like clockwork," or like a "well-oiled machine," and in contrast, when things are not going well, we speak of "breakdowns" or "things that need fixing." Along the same lines, we speak of organizations as having "inputs and outputs," which we seek to "maximize" and make "efficient." People in this framework, become "cogs in a wheel" or human "resources." Morgan (1997) argues that this mechanical way of thinking is deeply "ingrained in our everyday conception of organizations" (p. 6), and that it is almost impossible to think of organizations in new and, possibly more useful, ways.

In the next section, we provide one way of looking at organizations as being *complex ecologies* and suggest that in using this metaphor, we afford ourselves a richer and more provocative way of thinking about organizations, organizational change, and e-leadership. The ecological metaphor prevents us from merely seeing simple cause–effect relationships between the introduction of new technologies and their effects on organizations.

13.2.2 Understanding the Ecological Metaphor

Though we argue in favor of an ecological metaphor that has rich potential as a metaphor for thinking about organizations as complex ecologies, we must also note that the broader aspects of this framework are not original to us. As Zhao and Frank (2003) write:

> Viewing human institutions as ecosystems is not new. Bronfenbrenner (1979, 1995), Bronfenbrenner and Ceci (1994) and Bronfenbrenner and Morris (1998) has long been a champion in developing theories and conducting research about human development from an ecological perspective. Lemke (1994) uses the term "ecosocial system" in his application of the ecological approach to the study of cultural change. Bruce and Hogan (1998) analyzed technology and literacy from an ecological perspective. Nardi and O'Day (1999) refer to settings where technology is used as "information ecologies," which are systems "of people, practices, values, and technologies in a particular local environment." (p. 49).

In an ecological system, a point called "homeostasis" is achieved once there is a kind of balance or stability achieved by the different elements in a complex system that exist in state of a dynamic tension. The introduction of a new element, environmental factor, or species into the system can have different types of effects which are difficult to predict. The way that the system self-regulates to achieve a kind of stability or balance is indicative of the elements within the system and how they operate—particularly in relation to the new variable. So in this e-leadership metaphor, the introduction of ICTs becomes an essential element or variable added to the system, which it may deal with in various ways and with different results.

In the e-leadership literature, this type of view is described by Avolio et al. (2000) in terms of a socio-technical systems approach. Within this framework, the effectiveness of an organization is determined by the amount of alignment between social systems, technical systems, and the external environment. Thus, technologies and the social systems in which they are used are not simply correlative; in fact, they both influence and are influenced by each other in a reciprocal relationship. Leadership would clearly be impacted by this relationship, since it is a key element in the social systems and structures of organizations.

This new ecological approach toward organizations reconfigures the relationship between technology and leadership. A first step in this direction can be seen in the Avolio et al. (2000) proposal of a modified version of DeSanctis & Poole's Adaptive Structuration Theory (AST) framework. The original purpose of AST was to investigate and explain how people integrate technology into their work and was based on the idea that human action is guided by rules and resources (structures) that serve as models for the planning and completion of tasks. In this view, the effects of technology develop through interactions with organizational structures in which leadership plays a role; furthermore, the organizational structures themselves can be transformed by their interactions with technology. That is, not only can technology change as a result of the context in which it is used, but it also has the ability to influence that context in return. Therefore, it is critical that e-leadership be studied in context, as "in the case of e-leadership the context not only matters, it is a part of the construct being studied" (Avolio et al. 2000, p. 616). In the next section, we seek to better understand the *context* within which schools function.

13.3 The Educational Context and E-Leadership

The idea of leadership is contextually bound to the kinds of organizations being discussed. The goals of leadership in the corporate world are different than those of leadership in the nonprofit world or in the world of education. It is no surprise, therefore, that the idea of e-leadership will play out differently in education than in other organizations. Thus it is important to understand that schools both are and exist within a *complex socio-technological ecology*. We suggest that seeing schools as a complex ecology provides us with a sophisticated way of thinking that values the reality and organic nature of the organization, as well as the diverse interests of the various stakeholders in the process.

The ecological metaphor implies that rather than studying discrete factors seemingly acting independently of each other, we see schools as organic and dynamic structures, with complex nonlinear feedback loops, that defy easy predictability and control. In this view, schools are knowledge industries that are a complex system of many parts and relationships, incorporating both human actors (such as teachers, students, parents, administrators etc.) and nonhuman actors (e.g., physical settings, technologies such as computers and networks, curricula, subjects of teaching). These actors form a complex system where they interact with each other, in ways that continuously modify their relationships with each other, as they attempt to strike a stability and balance—their own "homeostasis" if you will.

Schools, of course, do not exist in isolation from the rest of the world. They are nested within hierarchies—for instance, school districts, which in turn exists within broader state and national educational systems. Teachers once again are a key component of this ecology—as they can function as gatekeepers to change or as agents of change and transformation.

Thus, understanding how ICTs influence and change the nature of leadership and teacher development requires a comprehensive and systemic approach that takes into consideration the nature of the actors, the environment, other facilitative forces, and the interactions among these components. This means that the introduction of ICTs into an organization such as a school does not lead to simple predictive and predictable effects. The complexity of an ecological system often works against such simple input-output models of cause and effect.

It follows from this perspective that the internal system of an organization or group—including institutional culture, levels of expertise, shared mental models, and the social interactions of its members—exerts a strong influence on any technologies to be used within it. Users frequently reject, resist, or adapt technologies in ways that go beyond their intended use, resulting in unexpected consequences. Since leadership plays a central role in guiding the internal systems of a group, it is particularly relevant to the emergent interplay between organizational structures and the technology integrated within them. That is, leadership can influence the social structures of an organization in ways that foster or hinder the implementation of technology.

Taking on an ecological framework helps us to push away from simplistic, deterministic, and linear approaches to thinking about technology and its role in educational contexts. Despite seemingly straightforward definitions, the conceptual understandings and resulting empirical study of e-leadership have been fairly inconsistent. Gurr (2004) identified three major categories/views of e-leadership that have sparked three different streams of research: "More of the Same," "Leadership Plus," and "Transformation" (pp. 116–117).

In keeping with existing research in educational technology integration, we suggest that this fits well with the *Replacement, Amplification, and Transformation* (or RAT) framework (Hughes et al. 2006) for thinking about ICT and leadership. We are careful to emphasize that while this three-fold categorization provides us with ways of thinking about how e-leadership can unfold, it is never a deterministic or predictive model. Once a technological variable (or multiple such variables, or ICTs) is introduced to a system, the results will depend on unique and dynamic systemic factors of the organizations or schools themselves. However, as such systems react dynamically to the element of ICT, and try to achieve a balance (or homeostasis) within the organization/school ecology, we suggest that the Replacement, Amplification, and Transformation model gives us three broad possible categories to understand how this can often play out.

13.3.1 Replacement, Amplification, and Transformation

The RAT framework emerged from scholarship that sought to better understand the manner in which teachers integrate technology in their teaching. Hughes et al. (2006) define three categories of teachers' integration of classroom technology, including: (a) Technology as Replacement; (b) Technology as Amplification; and (c) Technology as Transformation. Perhaps unsurprisingly, technology as "Replacement" refers to using technology to simply replace existing instructional tools. It is the most basic level of technology integration, in that there are no pedagogical changes. The new tool is simply swapped into the place of the old tool. However, technology as "Amplification" refers to using technology that somehow enhances or amplifies existing teaching practice and student learning. At this level, dramatic enhancement of learning does not necessarily happen, but in taking advantage of augmented technology affordances, digital tools are used to increase efficiency and productivity. However, at the technology as "Transformation" level, such tools are used in ways that fully and fundamentally alter (or transform) the pedagogy, how students learn, and perhaps even the subject matter. In this transformational place, the role of technology changes the teaching itself, the instructional methods, the work or role of the teacher, the learning process, and/or possibly the content.

We see a reasonably straightforward mapping of the RAT framework to that of e-leadership. Replacement involves a simple substitution of the new technology tool for the existing tool or method. Nothing is improved, as it is at best a neutral swap (or at worst a retrograde). Amplification does alter things to a degree, in offering some enhancement or improvement through technology use that allows something to be done better than before. Things do not change vividly though, until applying technology at the transformational level. This indicates an application that is not only fundamentally different from existing instruction, but in which the affordances of the technology, and its use, allow for a total reshaping of the variables in the situation—of how the teacher teaches, of what and how students learn, and even of the ideas in play. In the next section, we focus on each of these constructs in greater detail, in exploring and mapping them into an e-leadership model. By aligning these views with the RAT framework, we begin to discern a picture of the research that has been conducted, and the need for future investigation in the field. In each case, we look at it from the literature of business and management (given the preponderance of work in these domains) and then its consequences within educational contexts.

13.3.2 Replacement or "More of the Same"

In business. The first view stems from the business sector, and involves simply transferring traditional views of leadership to modern organizations, relabeling them as e-leadership—traditional ideas, with a contemporary name. This view has led to considerable conceptual confusion by using this new name only to refer to "more of the same" (Gurr 2004, p. 116). As in the description of replacement in the context of using technology, this "more of the same" view of e-leadership refers to simply replacing the label of leadership with e-leadership. There are no changes to the concept or the kinds of leadership behaviors that may be needed even though the environment (or organizational ecology) has changed significantly with the introduction of ICT.

In education. Within educational contexts, the "Replacement" model suggests a similar point of view, i.e., ICTs though introduced are often used for basic purposes that have been previously defined and are thus constrained by existing practices. Technologies are used to replace existing mechanisms. In the school context, this can be seen in the introduction of attendance systems, the use of spreadsheets for budget calculations, or classroom websites to share homework problems with students. In each of these cases, there has been no fundamental change in the administrative or pedagogical processes that existed before—apart from the fact that they have been replaced by ICTs. If we think of schools as a complex ecology, the replacement approach suggests the replacing of a key species with another—with no or little change to the overall ecological balance of the environment. Technologies that align well with existing practices get accepted faster than ones that may disrupt or change existing approaches. An example of this is the quick incorporation of PowerPoint or the under-utilization of smart-boards in the classroom context. In both cases, these technologies merely replace existing practices (the lecture mode) without causing any real change to teaching and learning.

In contrast, other researchers have argued leadership in ICT environments requires different skills (Gurr 2004). This leads us to a second view of e-leadership.

13.3.3 Amplification or "Leadership Plus"

In business. The second, what might be described as "leadership plus" (Gurr 2004, p. 117), builds upon traditional approaches to leadership, and is based largely on survey and interview data gathered from leaders in business. It is through the amplification of components of leadership that we begin to see how e-leadership departs from traditional views. Although there is still a belief in the importance of traditional leadership qualities, there is recognition that amplification of various elements is needed as technology is integrated into the context.

Phelps (2014) described a number of skills typically associated with traditional leadership frameworks that are important when harnessing the potential of technology. These include technical skills, communication skills, organization skills, team building skills, and flexibility and adaptability. In a study that focused on communication skills, participants from 54 major organizations in Romania, from state agencies to private businesses such as television stations and banks, agreed that the use of new types of communication helped to organize, control, and streamline communication and information. However, the respondents also felt that ICT-enabled forms of communication should not replace traditional forms, but should be used in addition to face-to-face communication, because traditional forms favored direct relationships with employees (Blau and Presser 2013). Leaders and employees recognized the importance of traditional communication skills, but saw positive results when those skills were augmented by technology.

In another study on communication skills in leadership settings, researchers chose five major businesses in Finland to investigate the importance of an e-leader's ability to build trusting relationships (Savolainen 2000). One factor that played an important role in an e-leader's level of trust were the processes and techniques used for communication. When the e-leader's communication was occasional and fragmentary, the employees experienced low degrees of trust. E-leaders who were most successful deliberately pursued trust-creation, which required time and continuing efforts. These leaders recognized their important role in trust-building and identified ICT as being integral to sustained communication with their employees (Savolainen 2000).

In education. In the educational context, the idea of amplification is often seen in the ways that technology can be introduced to a school or educational ecology for one purpose, and then its affordances allow for more or different amplifications of that original purpose. It can happen that certain technology might be introduced with the assumption that it provides a basic replacement, or perhaps a minor amplification of increased efficiency, of an older or more low-tech method. But once that technology takes effect within the school ecology, unintended consequences or results (for better and/or worse) will begin to unfold based on the factors at work in the complex system.

For instance, one might see a digital school attendance system introduced, and initially assume it will replace the old system for simple daily attendance. But the affordances of the technology within the school system may produce new effects. The digitized system will provide much more data, which could allow long-term close tracking of student attendance. This could lead to effects for individual students and policy changes impacting the group overall. The ability to put attendance or even grades online (or generate instantaneous robo-calls to home on these issues), can promote a different level of information for parents, and perhaps a different level of communication, connection, and interactions between parents and school-agents. So while a basic attendance (or grading) system through digitization was the initial plan, what ensues might be a different type of participation or relationship between stakeholders, a different means of data gathering on students, or other unplanned results. This is the amplification effect, in which technology's affordances are leveraged and the power of whatever you do with it becomes amplified. What we see here is that technology is introduced to the ecology and it does not just replace—but it also amplifies (i.e., it gives us something more, than just more of the same).

13.3.4 *Transformation: E-Leadership as Transformational Leadership*

In business. The third view, supported by a range of researchers, suggests that there are fundamental differences between traditional leadership and ICT-mediated leadership; furthermore, the interactions between technology and leadership may necessitate changes in our assumptions about leadership itself. This last view calls for a new type of leadership to address the challenges and opportunities presented by technology. This is transformational leadership. A transformational leader recognizes the ever-changing world in which she leads and leverages the power of various technologies to inspire change.

In a large-scale study for the European Commission, researchers found that there is a growing need for e-skilled professionals, especially e-leaders. E-leaders are a new type of leader essential to organizational innovation and competitiveness: "Effective e-leaders are capable of leading teams and managing technology systems in ways that achieve both local and global demands" (European Union 2013, p. 12). Along with a definition of e-leadership the researchers voiced a concern for the lack of current and future leaders who will be prepared to lead in transformational ways. There is recognition that the changing climate of organizations requires a different form of leadership, but there is a shortage of individuals who are capable of filling those roles.

Phelps (2014) outlined a number of technologies that have been identified as contributing to the intersection of technology and leadership. These include virtual teams, communications and social media, web-based collaboration tools, management systems, and content organization tools. An area from this list that has seen a substantial amount of study is the shared leadership that occurs in virtual teams or communities.

In a paper that explored the challenges of leading and facilitating digital collaborative learning, Harris et al. (2013) found that distributed leadership is integral to good digital collaboration and is an important determinant of collaboration in a virtual environment. Gurr (2004) argued that some form of dispersed leadership would be useful in conceptualizing e-leadership.

Malhotra et al. (2007) studied virtual teams to identify effective leadership practices. These practices included the ability to: generate and sustain trust using ICT, ensure understanding of diversity, effectively monitor virtual work, manage progress using ICT, extend the visibility of virtual members, and ensure that all members benefit from the team. Kerfoot (2010) stated that new skills are required for sustaining high performing teams across diverse boundaries.

In Education. The ongoing advancements in educational technology and lack of research make e-leadership in education an essential field of study (Jameson 2013). According to Jameson, the "take up of tech innovations has not been accompanied by critical reflection, professional development, and research on the education technology leadership and management functions that ideally should accompany effective implementation of learning technologies innovation in educational" settings (2013, pp. 890–891). Traditional views of leadership in education are changing—moving from leader-centered to models that resemble distributed leadership.

Gurr (2004) stated that e-leadership should be an important part of our view of educational leadership. Rapid developments in technology have led to new spaces for human interaction. Previous research distinctly separates the fields of leadership and educational technology. A crucial need is to bridge this gap to support successful learning and teaching with technology (Jameson 2013).

One of the few studies that has been conducted on e-leadership and education was a correlational study examining the relationships among demographic characteristics, leadership styles, technology acceptance, classroom anxiety, learning environments, and student satisfaction with course interaction/structure/support, in Taiwanese higher education. The findings of this study showed a significant correlation between teacher leadership style and student satisfaction with course interaction/structure/support. Those professors that exhibited transformative leadership styles had higher student interaction and satisfaction in their courses (Lin et al. 2010).

Franciosi (2012) argued that little attention has been given to leadership frameworks at the school, district, or government level. In a field characterized by technological innovation and change, leadership style is critical to facilitating successful use of technology that contributes to positive learning outcomes. Digital culture calls for a transformational leadership style—a move away from the traditional leader-centric form of leadership that is common in education. According to Franciosi (2012), educational leadership should be more flexible to cope with technology-driven changes and developments.

School leaders play crucial roles in the adoption of ICT. Schools are in the transition of re-culturing to accept teaching with information and communication technologies. Principals are the onsite educational leaders who shape and communicate visions of teaching and learning within their schools, and by their action or inaction influence school activity (Afshari et al. 2009; Otto and Albion 2002). In a study on the use of ICT in education in Norway researchers found that distributed forms of leadership led to an increased willingness by staff to incorporate ICT into their teaching (Ottestad 2013).

Evolution in higher education is not known for its speed. Our graduate preparation programs are holding on to core curricula in the midst of tremendous change. Online-only, nontraditional, and international students require us to adopt, adapt, and aspire to new heights. Social media provide conduits for connection, information dissemination, and conversation on a scale that far exceeds our bulletin boards and traditional communications channels (Stoller 2013).

> Leaders who can master social media will be well positioned to be leading in this new area and will be able to influence the new generation. Those who cannot are going to struggle and will see their influence diminish. There are many leaders who are trying to stem this tide; there are organizations in which people are not encouraged to join in with the rise of social media, as it is viewed as something the organization cannot control. One thing that

> can be pretty much guaranteed is that social media connections of tomorrow will not be the same as those of today – and leaders will need to keep up (Tredgold 2014, p. 10).

The rise of social media and mobile technologies has allowed "followers" to become loci of e-leadership, sharing information, and responding to events in a much more active way—as evidenced by the role social media users have played in responses to recent natural disasters and political uprisings. As Avolio et al. (2014) noted, these technologies open up "opportunities for followers to influence the leader and others via back-channel communication" (p. 110).

To summarize, we have argued that seeing organizations (specifically schools) as complex ecologies provides us with a far richer way of thinking about organizations, leadership, and the role of ICT. By conceptualizing ICT as one element of this complex ecology, we prevent ourselves from falling into the trap of technological determinism, i.e., simple cause and effect relationships between the induction of a new technology and its effects on organizations. Moreover, we suggest a three-fold way of thinking about how ICT's can influence e-leadership: by replacement, amplification, and transformation.

In the next part of the paper, we look more closely at one crucial component of the ecology of schools—namely teachers and teacher development.

13.4 E-Leadership and Teacher Development

Our definition of e-leadership describes it as "a social influence process" that takes advantage of ICT to produce changes in attitudes, knowledge, behavior, and performance. For instance, research has shown that a teacher's beliefs and attitudes are often strong indicators of their planning, instructional decisions, and classroom practices (Pajares 1992). More importantly, from the point of view of e-leadership, research has documented a relationship between the beliefs of teachers regarding implementation of reform efforts, and instructional decisions (Cornett et al. 1990; Crawley and Salyer 1995; Haney et al.1996; Hashweh 1996; McDevitt et al. 1993).

Though beliefs and attitudes are important predictors of how teachers work, the most significant influence on how teachers' actually practice is the *knowledge* they bring to the task. This becomes increasingly important in the world we live and work in today, which has been described as a knowledge economy—and schools, by extension, are a knowledge industry. Seeing schools as a knowledge industry implies that schools are an economic activity where success depends on obtaining, managing, and using knowledge. This is not to say that schools are not concrete objects with buildings, and infrastructure with pipes and wires and walls and playing fields, but rather that the core goal of school is "obtaining, managing, and using knowledge." And of course, teachers are crucial mediators in making this knowledge accessible and available to learners. This does not refer to one kind of knowledge.

In fact, one of the challenges we face today (with the rise of ICTs) is that certain kinds of knowledge are privileged while others receive less attention.

More specifically, it has been suggested that we need to distinguish between four kinds of knowledge: *know-what, know-why, know-how, and know-who* (OECD 1996). The first two of these focus more on explicit information (facts/information in the first case and scientific knowledge, theories/principles in the second case). The know-how and know-who are more tacit in nature—focusing on skills and capabilities in the first instance, and networks and social relationships between people in the latter.

Being knowledge industries, schools (and teachers) are at the forefront of the development of all four of these forms of knowledge. It is important to note that these distinct forms of knowledge are developed differently. Teacher education programs (and schools for that matter) have typically focused on the know-what aspect of knowledge with some emphasis on know-why. In contrast, know-how and know-who have not received as much attention. This is because these relatively tacit kinds of knowledge are developed by engaging with practical experience (such as professional apprenticeships and specialized day-by-day interactions) and teacher preparation programs have typically not emphasized such forms of learning. Teachers are critical knowledge workers according to this perspective. They are the crucial mediators between knowledge in the field or domain and the learner.

If, as we have argued, schools are complex ecologies, then this lack of emphasis on know-how and know-who presents a significant gap in how we think about teacher professional development in the domain of ICT. Clearly, teacher education and development needs to focus on the development of all four kinds of knowledge, though as described above the emphasis has been more on the first two forms rather than the last two.

Moreover, teachers involved in leadership must understand that the development of IT networks has exacerbated the distinction between these forms of knowledge. Certain types of knowledge (know-what and know-why) are easier to codify, reduce to information, and transmit with limited costs. Even as we celebrate the digital revolution, the rise of the information society, and the easy availability of resources such as digitized books, journals, images, video clips, sound and voice recordings, we need to acknowledge that there are forms of teacher knowledge (connected to leadership) that are essential and important but may be missed in our focus on discrete, easily digitized bits of information. This has consequences for how we view leadership and teacher development.

Finally, teachers need to understand how organizations such as schools function. In other words, they need to develop an understanding of the fact that schools are a complex knowledge ecology—and that actions and reactions in such an environment are often nonlinear and nondeterministic. The mere introduction of ICTs into the school environment will not ensure that the processes by which the organization functions will necessarily change or improve. As we have argued, ICTs usually just function as replacements or amplifiers of existing tools and processes. To truly see the transformational nature of ICTs for e-leadership requires looking beyond the affordances of the tools to developing a better understanding of the social and interpersonal structures that guide organizations. It is only by leveraging these broader factors (that often go beyond the technical) that true transformational e-leadership can be achieved.

13.5 Conclusion

In this paper, we have argued that though there appears to be great potential for ICTs to change the nature of leadership in educational organizations, not much has actually been done in this area. Most of the discussion has been prompted by research or thinking in the arena of business and has been dominated by a techno-centric deterministic perspective, which suggests that the mere introduction of new technologies will lead to transformational change in organizations. We have argued for a far more complicated picture, grounded in our understanding of organizations such as schools as being complex knowledge ecologies. An important consequence of seeing educational institutions as knowledge economies is that we must note the range of ways in which technologies "fit" into the eco-system (which we suggest can be seen as leading to replacement, amplification or transformation of the organization and hence the nature of leadership). Achieving genuine transformation requires that teachers and other stakeholders have to become sensitive to the complex social, cultural, and contextual aspects of organizations. This requires the development of knowledge beyond just know-what and know-why (aspects of knowledge that are often discrete and measurable), but also of know-how and know-who (both of which are far more complicated to understand). It is only then that the transformational potential of ICTs and e-leadership can be realized.

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Chapter 14
Comparative Study on International Policies for Teachers' ICT Capacity-Building

Jianhua Zhao, Pengge Yao and Jing Kong

Abstract A series of policies to promote teachers' ICT capacity-building have been published and implemented all over the world. In this paper, the policies for teachers' ICT capacity-building in the United States, South Korea, Singapore, Australia, Britain, and China have been selected and analyzed in five dimensions: policy contents, policy goals, policy characteristics, ways of implementation, and policy evaluation. The results indicate that the policies for teachers' ICT capacity-building worldwide have been introduced in stages with different focuses but have continuity. The contents have gradually moved from technology literacy to knowledge deepening to knowledge creation finally. The supporting policies have provided a guarantee for the implementation of teachers' ICT capacity-building. A third-party evaluation is recommended to ensure the effectiveness of the policy of teachers' ICT capacity-building.

Keywords ICT in education · ICT capacity-building · Policy · International comparison

14.1 Introduction

In recent years, educational practice has been greatly affected by the rapid development of ICT. How to integrate information technology into education has become a hot issue in the field of education all over the world. Generally, ICT in

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educational can be divided into four stages: starting stage, application stage, integration stage, and innovation stage (Majumdar 2005). At present, China is in a critical period, moving from the ‘application stage’ to the ‘integration stage’, so how to realize a deep integration of ICT and education will naturally be the focus in China in the next decade (Zhu et al. 2014). As teachers are the direct participants to promote ICT in education, their ICT competencies are of great importance in the application of ICT in education. Therefore, to improve teachers’ ICT competencies and to promote the integration of information technology and education, which serve as the basic means of ICT in educational in schools, have become important tasks for many countries and international organizations (World Bank 2010). In order to promote teachers’ professional development via information technology, supporting policies have been introduced by many countries and international organizations The United States, South Korea, Singapore, Australia, and Britain are among the representatives. Many participants involved in the research and implementation of ICT in education, such as international organizations, well-known enterprises, and academic organizations, have studied teachers’ ICT capacity-building from different perspectives. In 2011, UNESCO together with other units constructed the UNESCO ICT Competency Framework for Teacher, which had a far-reaching impact on teachers’ ICT capacity-building (UNESCO 2011). UNESCO also carried out many other projects to promote teachers’ ICT capacity-building worldwide, such as Effective Integration of ICT and Teaching, ICT for Distance Teacher Education, Mobile Technology-supported Teachers’ Professional Development. What is more, Intel’s Future Education Program and One-to-One E-learning Project, Microsoft’s Partnership for Student, Apple’s Distinguished Educator Program, and HP’s Catalyst Initiative have also been designed and implemented for the same purpose.

Policies are essential in teachers’ ICT capacity-building for their guarantee and support. This study, based on the comparison and analyses of the policies for teachers’ ICT capacity-building all over the world, aims to find the experience and laws of those policies and then to provide references for the development of ICT policies in China. Different countries have different cultures, economies, and politics, so when it comes to the policy of teachers’ ICT capacity-building, they also have different goals and ways of implementation.

Public policy studies have contributed immensely to the research design of this study. For example, George McCall and George Weber proposed a two-step analytical model, in which both policy contents and policy process were analyzed. The policy contents include policy goals, route selection, intentions, and action plans, while the policy process covers policy behaviors, policy choices, policy implementation, and policy evaluation (McCall and Weber 1984). Weiqing Meng, a Chinese scholar, has set up a three-dimensional analytical framework to analyze educational policy, which is composed of three elements: value, content, and process. The value mainly deals with the value criterion of educational policy; the content is for the goal, means, and subjects; and the process focuses on the whole process of educational policy from formulation to implementation to evaluation (Meng 2008). Meanwhile, Charles Wolf Jr and David Phillips have suggested approaches and procedures of comparative study on policies (Wolf 1993; Phillips and Ochs 2004). Based on the approaches and models adopted in comparative study of public policy, combined with the actual status in various countries, in this study, an analytical framework has been established, comprising five analysis dimensions: policy goals, policy contents, policy implementation, policy characteristics, and policy evaluation.

In this study, research subjects are policy documents for teachers' ICT capacity-building. These documents mainly come from countries with typical and innovative contributions in the field of teachers' ICT capacity-building, such as the United States, South Korea, Singapore, Australia, Britain, and China as well. Comparative study is used as the research method. Research data are mainly from the network literature (e.g., national and institutional websites, thematic websites, Web magazines, the database and repository issued through the network), supplemented by some other literature (e.g., journal articles, conference proceedings, publications, etc.), and expanded data from schools and institutions at home and abroad via emails. An analytical framework is built based on the research questions (as shown in Fig. 14.1). Then, the data collected are compared, processed, interpreted, and evaluated according to the analytical framework, and finally conclusions and implications are drawn (Zhongzheng 2008). In this study, horizontal comparison and vertical comparison have been combined. On one hand, the courses of teachers' ICT capacity-building worldwide have been reviewed; on the other hand, the experiences in different countries and organizations have been analyzed. As a result, the implications for policy-making in teachers' ICT capacity- building can be worked out.

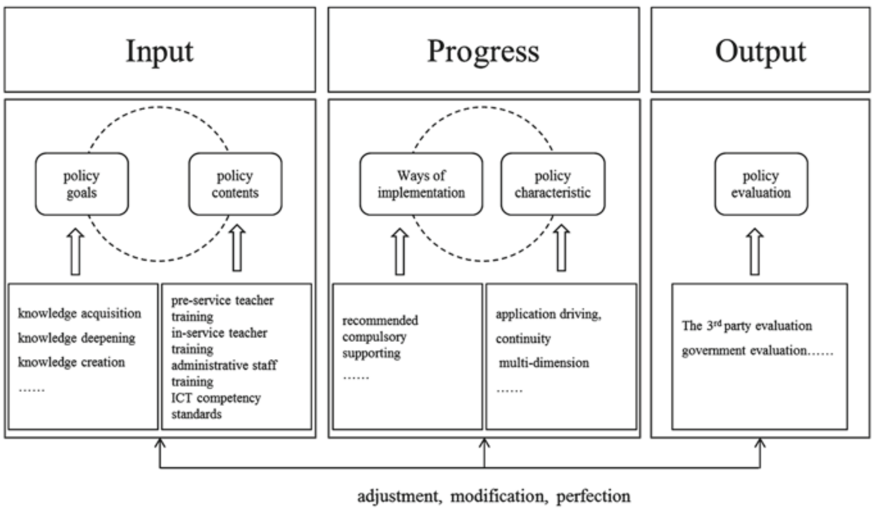

Fig. 14.1 Analytical framework for teachers' ICT capacity-building

14.2 Policy Analysis of Teachers' ICT Capacity-Building

Many countries have formulated policies to guarantee the development of teachers' ICT capacity-building. After a brief review of the relevant policies and developmental courses in the United States, South Korea, Singapore, Australia, Britain and China, they have been analyzed from five dimensions.

14.2.1 American Policies for Teachers' ICT Capacity-Building

The U.S. government has paid much attention to the application of ICT in education. At the beginning of 1996, the National Education Technology Plan has put forward that future teachers should be equipped with necessary skills to integrate technology in their teaching practice (U.S. Department of education 1996). In 1999, the Federal Department of Education launched Preparing Tomorrow's Teachers to Use Technology—a big founded project for pre-service teachers to use technology in teaching practice (U.S. Department of Education 1999). In order to accelerate the development of ICT in education, the U.S. Department of Education has issued three national educational technology initiatives between 2000 and 2010, and made clear strategic deployment for teachers' ICT capacity-building respectively. For instance, NETP2000 has mentioned that all teachers should effectively use technology to help students realize higher learning achievements (U.S. Department of Education 2000). As for lack of training and understanding of how to use technology to facilitate learning, NETP2004 has adjusted the investment structure of ICT in education and improved the efficiency of the application of technology through systematic reforms (U.S. Department of Education 2004). In 2010, the fourth NETP was formulated by the Obama government, and the strategic objective in teaching has been clearly defined as 'professional educators should receive individual or group support via technology to teach more effectively' (U.S. Department of Education 2010).

The US has paid much attention to the standard construction of teachers' ICT capacity-building, such as the national standard, organization and state standards, pre-service teacher standards, and on-the-job training standards. These standards can be divided into two categories: standards for teachers' professional competencies and curriculum standards or qualification standards for teachers' training institutions. In 1993, the American International Society for Technology in Education (ISTE for short) introduced National Education Technology Standards for Teachers (NETS.T for short), and till 2008, it has been revised four times. In 2000, NETS.T had 6 competencies and 23 indicators (ISTE 2000); while the new version in 2008 included 5 competencies and 20 indicators as for teachers' ICT capacity-building (ISTE 2008) (see Table 14.1).

Table 14.1 Summary of American policies for teachers' ICT capacity-building

	Policy content	Policy goal	Implementation approach	Policy evaluation
NETP 1996	In-service teachers pre-service teachers	All teachers can help students to learn through computers and internet	Recommended policies	–
NETP 2000	(1) To strengthen student teachers' development; (2) To improve the quality of teachers' professional development; (3) To Provide supports for teachers' teaching; (4) To set up standards of teachers education institutions and curriculum evaluation	All teachers can effectively use technology to promote students' high level of learning	Recommended policies; National Education Technology Standards For Teachers (1st edition)	–
NETP 2004	To improve teachers' training and provide digital training for each teacher	All teachers can efficiently use technology to improve learning	Provide suggestions for states, districts and schools; National Education Technology Standards For Teachers (2nd edition)	–
NETP 2010	Good preparations and professional learning experience to use technology; To cultivate a faculty team good at using the Internet to carry out teaching; To use information technology to create teacher's lifelong learning network	To improve students' learning by Unicom Education	Recommended policies	–

14.2.2 South Korea's Policies for Teachers' ICT Capacity-Building

South Korea has made significant achievements in the development of teachers' ICT capacity-building, which has close relationship with the policies of ICT in education and teachers' ICT capacity-building made by the government of South Korea.

Since 1996, the South Korean government has promulgated ICT in educational initiatives four times, and each time made strategic deployment for teachers' ICT capacity-building (KERIS 2013). In 1997, the South Korea Ministry of Education formulated Plans to Strengthen Teachers Information Ability. According to the plan, 25 % of all teachers are to be trained to develop their ICT competencies each year, and all the teachers have the chance to be trained at least once in the following 4 years (MEST 2000). From 2001 to 2003, South Korea has adopted various ways to improve teachers' ICT competencies, including training one specialist in information technology for every school, training one maintenance technician for every 5 schools, training a third of CEOs in educational institutions every year, and providing a school-based ICT training for all the teachers for not less than 15 h (Li 2003). In South Korea's latest development strategy, the development of teachers' competencies has been regarded as an important support to cultivate innovative talents. Therefore, supporting tools based on teachers' personal experiences have been developed and popularized to build supporting mechanisms for improving teachers' competencies. In addition, the South Korea government has built up an educational community of practice for teachers known as 'Education Café', where teachers can select digital resources of high quality and share their own resources and experiences with other teachers (Edunet). What is more, many training programs for in-service teachers have been implemented in South Korea to encourage teachers to apply ICT better, and excellent teachers can even receive a small amount of bonus provided by the Educational Information Research Institute (Oh 2009). In order to evaluate the effects of these policies, corresponding evaluation will be conducted by South Korea's ICT Research Institute each year, and an annual white paper will also be published.

In order to reform traditional ICT training models, South Korea's Education and Human Resources Development formulated ICT Skill Standard for Teacher (ISST for short) in 2001. Based on teachers' different positions, four ranks have been divided in ISST: the teacher, the minister of education information, the school superintendent (vice-principal), and the principal (Cui et al. 2011), different ranks with different basic ICT competencies. In 2002, South Korea's Education and Human Resources Development modified ISST and readjusted teachers' positions to the teacher, the school superintendent (vice-principal), and the principal. The main points of Korean policies for teachers' ICT capacity-building are shown in Table 14.2.

14.2.3 Singapore's Policies for Teachers' ICT Capacity-Building

Singapore's success in the construction of ICT in education is owed to her overall design implemented at the national level. In 1997, the government of Singapore introduced the first MasterPlan for ICT in education (MP1 for short) (1997–2002)

Table 14.2 Analysis of South Korea's policies for teachers' ICT capacity-building

	Policy contents	Policy goals	Way of implementation	Policy characteristics	Policy evaluation
Master Plan1 (1996–2000)	Providing training courses for teachers, including special courses and general courses	Improving teacher information literacy	Formulating plans to strengthen teachers' ICT competencies; Promoting the implementation of ICT in educational in primary and secondary school to establish; Formulating basic laws of information communication and Informationization Promotion Act	Sustainable and systematic policy; Adjusting the policy in time based on the real status	Government's white paper
Master Plan2 (2001–2005)	Implementing teachers ICT capacity-building plans; Performing ICT training via online education and training centers; Establishing ISST	Improving teachers' ICT competencies	–	ditto	Government's white paper
Master Plan3 (2006–2010)	Establishing ISP unified information system for teacher training; Establishing service system for teacher training; Establishing various long-distance training centers to carry out e-learning training	Using ICT to reform teachers' ways of teaching	Implementing plan for substantiality and advancement of e-learning for reforming: schools and expanding educational opportunities	ditto	Government's white paper

(continued)

Table 14.2 (continued)

	Policy contents	Policy goals	Way of implementation	Policy characteristics	Policy evaluation
SMART education (2011–now)	Cultivating professional lecturers; Training project development; Activating learning communities; Popularizing and using digital materials and promoting teachers' competencies; Personalizing training	Strengthening teachers' competencies in SMART education	Implementing supporting plans for the development of teachers' competencies; Performing high quality training programs	ditto	Government's white paper

(Ministry of Education, Singapore 1997). MP1 attached great importance to the integration of technology into school education to meet the challenges of the twenty-first century. When MP1 was launched, for lack of human resources, senior lecturers of information technology were first trained. Then these lecturers began to train some experimental schools in the first stage. In the second stage, the trained experimental schools took responsibility for 3 or 4 nonexperimental schools, respectively, and so on. Meanwhile, the senior lecturers worked as consultants to all schools. MP1 encouraged research institutes, companies, and information technology professionals to participate in the process of teachers' capacity-building and provide guarantee of theories and repositories for schools. In Singapore, all primary and secondary school teachers must experience special training provided by the National College of Education, which is in charge of corresponding ICT training plans and makes sure that the trainees should obtain basic ICT competencies for their teaching.

In 2002, the government of Singapore launched MP2, the second phase of ICT in education (2003–2008) (Ministry of Education, Singapore 2002). MP2 proposed a systematic plan for the application of information technology in teaching. Also, overall solutions were put forward, stressing the integration of information technology into a new teaching system and exploring ways of integration. The objectives of teachers' ICT capacity-building in MP2 are to build stable professional and teaching staff, to support schools' autonomy to use information technology, and to strengthen the school leaders' ICT capacity-building.

In 2008, the government of Singapore introduced MP3, the third phase of ICT in education (2009–2014) on the basis of previous work (Ministry of Education, Singapore 2008), which made systematic thinking about the application of information technology in teaching methods, teaching evaluation to improve students' abilities to use information technology. Next, the Ministry of Education set about building an ICT professional development framework for the purpose of making all school teachers and administrative staff learn to use ICT, directing schools to implement plans of ICT in education successfully (Cheah 2010). Although no plan was used to examine teachers' ICT competencies, teachers were encouraged to reach the basic standards of ICT in education for students (Ministry of Education, Singapore 2010). Singapore's Ministry of Education launched the ICT comprehensive mentorship program to promote ICT results to help teachers to apply ICT skillfully in their own disciplinary. After strict training, ICT mentors improved their own teaching skills and assist their peers to create and nurture learning communities. Table 14.3 reflects some main points of the policies for teachers' ICT capacity-building in Singapore.

Table 14.3 Analysis of Singapore's policies for teachers' ICT capacity-building

	Policy contents	Policy goals	Ways of implementation	Policy characteristics	Policy evaluation
Master Plan1 (1997–2002)	Focusing on in-service and pre-service teacher training	Training teachers' competencies of integrating ICT into curriculum; Cultivating pre-service teachers' core abilities of e-teaching	Establishing computer purchase program for teachers; Introducing teachers incentive mechanism	The philosophy of thinking school, learning nation	none
Master Plan2 (2003–2007)	Establishing integrated, sustained models for teachers' professional development; Promoting digital learning	Teachers can use ICT to promote self- professional development	Launching a series of projects to promote the implementation of the policy; Introducing teachers' incentive mechanism; Providing schools with more autonomous rights; Providing customized training programs for teachers' professional development by MOE	The philosophy of less teaching, more learning	none
Master Plan3 (2009–2014)	Cultivating teachers' design abilities under the informationization environment; Promoting students' autonomous learning and collaborative learning	Teachers can provide students with learning experiences under the informationization environment	Launching ICT mentor project; Promoting Propel-T project; Guiding teachers to develop technology-based SEED-ICT project; Promoting We-Learn Portal project	The reforming philosophy of all done for students' growth	Evaluation conducted by MOE

14.2.4 Australian Policies for Teachers' ICT Capacity-Building

The Australian federal government is committed to carry out reforms in the field of education, integrating digital technology into schools to support teaching and learning. In 2008, the Digital Education Revolution was launched, aiming at providing sustainable and meaningful reforms in Australian schools to help students make preparations for future education, training, living, and working in the digital world (Wang 2012). The Digital Education Revolution involves infrastructure, construction of teaching team, reforms in teaching and learning methods, etc. The main points of Australian policies for teachers' ICT capacity-building are shown in Table 14.4.

14.2.5 British Policies for Teachers' ICT Capacity-Building

Britain is the earliest country that applied computers to education in Europe. Since the 1980s, the British government began to pay attention to the application of information technology in education, and launched a series of policies, laws, and regulations to ensure the smooth implementation of ICT in education, such as Microelectronic Education Program, the five-year 'UK Network Year' plan, 'Information Technology' served as 'National Curriculum', and so on. The British government emphasized the construction of teachers' ICT capacity-building, which is reflected in the national policy of ICT in education. In 1998, the British government launched 'National Grid for Learning', and according to the plan, till 2002, all teachers can use information technology in teaching, and the library staff should also take similar training. Meanwhile, it is clarified that pre-service teachers (school graduates) need to have a good command of information technology. Some measures were taken to evaluate the pre-service teachers' ICT competencies. In 2005, Britain issued 'E Strategy: Harnessing Information: Transforming Learning and Children's Service', the purpose of which was to create a more personalized service environment for the development of individual potentials, and provide training for teachers to transform their teaching modes. In 2008, Britain issued 'Harnessing Technology: Next Generation Learning (2008–2014),' aiming to build the information system of self-confidence, and issued 'Next Generation Learning: Implementation Plan 2010–2013,' mainly about action plans and targets from 2010 to 2013 (BECTA 2008); the relevant points are shown in Table 14.5.

Table 14.4 Analysis of Australian policies for teachers' ICT capacity-building

	Policy contents	Policy goals	Way of implementation	Policy characteristics	Policy evaluation
Digital education revolution (2008–2013)	Implementing teaching plan in digital age; Improving the teaching mode and strengthening the application of digital resources in quality education; Applying teachers' ICT competencies standards to pre-service training and in-service professional development; Communicating effective practical experience in schools' management and departments (Tang, 2009)	Teachers can design student-centered learning plan, and make good use of modern learning resources and activities	Formulating 'Success through Cooperation' and 'Digital Education Revolution Implementation Roadmap' to provide guidance for digital education revolution	Taking the initiative in the world for dealing with the economic crisis	Introducing the third-party evaluation

Table 14.5 Analysis of British policies for teachers' ICT capacity-building

	Policy contents	Policy goals	Ways of implementation	Policy characteristics	Policy evaluation
NGFL (1998)	Training in-service teachers and library staff; Cultivating ICT awareness and competencies of pre-service teachers (school graduates)	All teachers can use information technology to teach, and pre-service teachers have a good command of information technology	Providing primary and secondary school teachers with educational resources and teaching guidance through the network; Putting the use of funds to legislation, and providing supporting plans for implementation	Formulating some measures to evaluate pre-service teachers' ICT competencies	Initiating a series of evaluation programs, such as ImpaCT2 and Pathfinder program to evaluate the effects on children by ICT and ICT policy from local education bureau respectively; Evaluating the effectiveness of policies on national education technology and its investment by OFSTED
E-strategy-harnessing technology: Transforming learning and children's services, 2005–2010 program (2005)	Providing training for in-service teachers, and transforming teachers' teaching modes	Creating a more personalized service environment to maximize the individual potentials	Sharing experience, and enhancing the learning effects through attractive courses and online courses		

(continued)

Table 14.5 (continued)

	Policy contents	Policy goals	Ways of implementation	Policy characteristics	Policy evaluation
Next generation learning: implementation plan 2010–2013 (2010)	Emphasizing the continuing education and skills training, realizing the transformation of the applications of technology in education and skills	Helping people use technology to learn and work efficiently, and using information technology with more confidence under the guidance of experts	Providing comprehensive, high-quality teaching supports, tools and resources for teachers to enhance teachers' status and professional knowledge	Providing 'Next Generation of Learning Awards'	This program is proposed with the improvement of UK's continuing education quality, with the attention to the continuity and application orientation of the policy

14.2.6 Chinese Policies for Teachers' ICT Capacity-Building

The Chinese government has attached great importance to teachers' ICT capacity-building, and as a result, a series of policies for promoting teachers' professional development using ICT have been promulgated and implemented. In July 2001, the Tenth Five-year National Education Program proposed to achieve a breakthrough in the construction of lifelong education system, education modernization, and ICT in education, also put forward specific requirements for teachers' application of information technology to implement modernized teaching (Ministry of Education, China 2001). In August 2001, the Ministry of Education proposed the proportion of using multimedia in teaching in colleges and universities to be not less than 30 %. This policy effectively promoted pre-service teachers' ICT capacity-building. In 2002, the Ministry of Education issued the Views on Promoting the Construction of Informationization of Education, which suggested that during the period of the Tenth Five-year Program, the construction of ICT in education was to cultivate primary and secondary school teachers with innovation and practical capabilities, and to improve primary and secondary school teachers' information literacy (Ministry of Education, China 2002). In 2003, the Ministry of Education released the Guidance on the Implementation of the National Education Network Alliance for Teachers, which was committed to realizing the goal of "harnessing information technology to stimulate the modernization of education for teachers, sharing high-quality education resources among primary and secondary school teachers of different levels and in different regions, and comprehensively improving the quality of education for teachers" (Ministry of Education, China 2003). In December 2004, the Ministry of Education promulgated and implemented the Educational Technology Competency Standard for Primary and Secondary School Teachers (Trial), in which requirements for primary and secondary school teachers, administrative staff, and technical staff were proposed, and it was regarded as the fundamental basis for the construction and evaluation of ICT competencies. In April 2005, the ministry issued the Announcement on the Implementation of the National Primary and Secondary School Teachers' ICT Capacity-building Plan, in order to improve primary and secondary school teachers' ICT competencies, to promote the application of technology in teaching, to establish ICT training and assessment system for primary and secondary schools teachers, and to organize ICT training (Ministry of Education, China 2005).

In order to strengthen teachers' education, deepen teacher's educational reform, innovate the cultivation mode, and improve teachers' ICT competencies as put forward in the National Medium-and-long-term Educational Reform and Development Plan (2010–2020), the ministry issued a series of policies for guidance and arrangement to carry out long-distance training, improve training system, promote the network alliance program, improve normal students' information literacy, and use information technology to promote teaching competency (Ministry of Education, China 2010, 2011). In 2012, the State Council promulgated the

Views of the State Council on Strengthening the Construction of Teachers' Educational Reform (The State Council, China 2012) and The Ministry of Education, National Development and Reform Commission, and the Ministry of Finance jointly issued the Views on Deepening the Educational Reform for Teachers. These policies aimed at promoting the deep integration of information technology and education for teachers, constructing the network research community, and lifelong learning support service system to promote teachers' autonomous learning. The latter also proposed to establish the school-based teacher training system with normal universities as the main body, teacher training institutions, and long-distance education as the support to realize the innovation of the teacher training mode. The relevant points are shown in Table 14.6.

14.3 Comparative Studies

Based on the comparative analytical framework, combined with the policies for teachers' ICT capacity-building worldwide, five aspects of these policies will be compared and analyzed.

14.3.1 Policy Goals

The policy goals refer to the levels that each country expects to reach at different stages of ICT in education through a series of actions and plans. Generally, different policy goals will lead to different focuses, ways of implementation, etc., in the process of ICT in education. Internationally, the policy goals of teachers' ICT capacity-building conform to the description of teachers' ICT competency standards, which are put forward by UNESCO (UNESCO 2011). Table 14.7 provides a general understanding of the policy goals of teachers' ICT capacity-building in different countries.

From the we can conclude that the goals of teachers' ICT capacity-building worldwide have experienced transformation from 'computer education' to 'technology literacy', later to 'knowledge deepening,' and eventually, to 'knowledge creation.' The goals are different at different stages of ICT in education, but with a certain gradient and continuity. That is to say, only after the goals of one stage have been fulfilled can the next stage be moved to. For example, USA, South Korea, and Singapore all have put forward explicitly the goals of teachers' ICT capacity-building at various stages of development in their plans for ICT in education.

The ICT Competency Framework put forward by UNESCO has covered three continuous stages of teachers' professional development: technology literacy, knowledge deepening, and knowledge creation. Among them, 'technology literacy' focuses on making students learn better with ICT tools. 'Knowledge deepening'

Table 14.6 Analysis of Chinese policies for teachers' ICT capacity-building

	Policy contents	Policy goals	Ways of implementation	Policy characteristics	Policy evaluation
10th Five-year Plan (2000–2005)	Realizing ICT in educational of pre-service teachers; Improving in-service teachers' competencies; Formulating professional competency standards for teachers	Building a national educational network system for teachers' ICT in educational; Significantly improving the information literacy of primary and secondary school teachers; Promoting the integration of information technology into the curriculum; Exploring the effective modes of teacher education in the information environment	Implementing the national teachers education network alliance program; Implementing primary and secondary school teachers ICT capacity-building plan	Setting up a committee of experts, and forming a series of policies	none
11th Five-year Plan (2006–2010)	Carrying out integration of teacher training, evaluation and certification by using ICT	Improving teachers' teaching competence in effectively using modern educational technology	Implementing national long-distance training programs and national rural teachers' training project in West China;	Changing from macro-guidance to project advancement; Inserting the curriculum standards and profession standards	none
12th Five-year Plan (2011–2015)	Promoting teachers' ICT competencies; Improving ICT in educational leadership, optimizing the training system of talents; Developing new ICT standards for teachers	Improving teachers' ICT competencies	Implementing the national training programs, the information competency promotion project for primary and secondary school teachers, and information technology leadership development project for principals	Integrating ICT competency into teacher education curriculum standards and profession standards	none

Table 14.7 Comparative analysis of policy goals of teachers' ICT capacity-building worldwide

Country	Technology literacy	Knowledge deepening	Knowledge creation
USA	NETP 1996 NETP 2000	NETP 2004	NETP 2010
South Korea	MasterPlan1 MasterPlan2	MasterPlan3	SMART education
Singapore	MasterPlan1	MasterPlan2	MasterPlan3
Australia	unknown	Digital education revolution	–
Britain	NGFL	E-strategy; Next generation learning	–
China	10th five-year Plan; 11th five-year Plan; 12th five-year Plan	China	–

pays attention to whether students can understand school knowledge deeply and apply what they have learned in the complicated, real world to solve problems. As for 'knowledge creation,' it mainly cares about how to facilitate students to create new knowledge required by a harmonious, substantial, and prosperous society. When it comes to the Chinese policy goals for teachers' ICT capacity-building,the stages and gradient of the goals have not been stressed much. Their policies focus on computer education and the transformation of pedagogy supported by technology literacy and information technology.

14.3.2 Policy Contents

The policy contents of teachers' ICT capacity-building that address the main fields of teachers' professional development in a country or an international organization play a very important role. From the above analyses and comparisons of the policy contents of some main countries, it is found that the policy contents of ICT in those countries mainly include pre-service teacher training, in-service teacher training, information technology leadership development, and teachers' ICT competency standards (see Table 14.8).

From the table it can be concluded that in terms of the policy contents of teachers' ICT capacity-building, three fields have been emphasized in each country: ICT capacity-building for pre-service teachers, ICT capacity-building for in-service teachers, and information technology leadership development for principals and administrative staff. However, different countries have different focuses at different stages, which can be specifically described as from focusing on pre-service teachers' ICT capacity-building to the integration of pre-service teachers training

Table 14.8 Comparative analysis of policy contents of teachers' ICT capacity-building worldwide

Country	Pre-service teacher training	In-service teacher training	Information technology leadership development	Teachers' ICT competency standards
USA	✓	✓	✓	✓
South Korea	✓	✓	✓	✖
Singapore	✓	✓	✖	✖
Australia	✓	✓	✓	✖
Britain	✓	✓	✖	✖
China	✓	✓	✓	✓

and in-service teachers training, certification and evaluation, and then to teachers' continuous, lifelong professional development via ICT.

Besides, corresponding teachers' ICT competency standards and the system of teachers' evaluation, recruitment, and certification have been established to promote teachers' ICT capacity-building all over the world. ISTE in USA published two different versions of evaluation standards to evaluate teachers' ICT competencies. China issued two versions of teachers' ICT competency evaluation standards in 2004 and 2014. While South Korea and Singapore have no such evaluation standards, they use guidelines for teachers' competency development (Bakia et al. 2011).

14.3.3 Policy Characteristics

In the process of formulating policies, every country and every international organization has shown its own characteristics owing to their different economies, cultures, and societies. To sum up, three main characteristics are presented: application driving, continuity, and multidimensional policy design (see Table 14.9).

Table 14.9 Comparative analysis of policy characteristics of teachers' ICT capacity-building worldwide

Country	Application driving	Continuity	Multidimensional
USA	✓	✓	✓
South Korea	✖	✓	–
Singapore	✓	✓	✓
Australia	Unknown	✓	–
Britain	✓	✓	✓
China	✖	✖	✓

From Table 14.9, four main characteristics are obvious in each country's teachers' ICT capacity-building: goal-oriented policies, application driving, supporting policies, and the continuous and multidimensional policy design. First, all countries have set distinctive goals to guide teachers in the process of their ICT capacity-building. Second, in order to motivate schools and teachers to participate in their ICT competency development, it is recommended that the government provide corresponding proposals, while schools and teachers choose the most suitable projects and approaches according to their own needs. USA and Singapore have set good examples in this aspect. Third, all the countries care much about the continuity and multi dimension of the policies. The performance of the new plan is always based on the previous implementations with continuous adjustments. Furthermore, in order to ensure smooth implementation, USA, Singapore, and China have made a series of supporting policies centered on the core policy of ICT capacity-building, and then formed a multidimensional policy system to guarantee the whole benefit.

14.3.4 Ways of Implementation

It is by certain means that the policy of teachers' ICT capacity-building can demonstrate the best effect on improving teachers' ICT competency. There are many ways for various countries to implement their policies, including issuing compulsory policies with top-down implementation, introducing recommended policies for local schools to choose from, and promulgating supporting policies to encourage more engagement. The ways of implementation are compared and analyzed in Table 14.10.

Table 14.10 illustrates that there are several ways of implementing policies for teachers' ICT capacity-building worldwide:

(1) There exist both government-dominated compulsory policies and recommended policies, and the latter are generally introduced by the government for local schools and teachers to choose from.
(2) In the process of implementation, the government would promulgate supporting policies through various ways, such as legislation. For example, USA once put 'No Child Left Behind' into the law. By legislation, the implementation of the policy of teachers' ICT capacity-building can be enhanced. Singapore has established awards and scholarships to outstanding teachers who creatively use ICT in their teaching. In the mid-1990s, South Korea developed related laws (e.g., Basic Law of Information and Communication, Information Promotion Law), which laid the foundation for improving teachers' ICT competency in the country.
(3) During implementation, international societies attach great importance to the cooperative participation of multiple forces. Take USA as an example. The American government pays much attention to cooperation with companies,

Table 14.10 Comparative analysis of ways of implementation of teachers' ICT capacity-building worldwide

Country	Compulsory policy	Recommended policy	Supporting policy	Participants
USA	✖	✓	✓ (legislation)	Federal government, state government, nonprofit organization
South Korea	✓	✓	unknown	MOE, KERIS, local education bureau
Singapore	✓	✓	✓(incentive measure)	Ministry of Education and Technology, IT companies
Australia	✖	✓	✓	Federal government, state government, local government, private institution
Britain	✓	✖	✓	Central government, local authority, Ministry of Education, BECTA
China	✓	✖	✓	Ministry of Education, local government, some state-owned enterprises

colleges, and universities and nonprofit organizations, making full use of the external forces to promote teachers' ICT capacity-building.

(4) Teachers' professional development activities organized by the government focus on teachers' ICT capacity-building at preliminary stage (such as IT literacy).

(5) The responsibilities for teachers' professional development activities to develop higher ICT competencies (such as knowledge deepening, knowledge creation, etc.) shift down from the government to the faculty and individual.

(6) Teachers' rights of choice, autonomy, and initiative are among the key factors in teachers' professional development activities. What is more, the design of the training contents of teachers' professional development activities should be in accordance with teachers' real needs.

14.3.5 Policy Evaluation

The policy evaluation is of great importance in measuring the effects of the policy, summarizing the experience of promulgating the policy, finding out problems, and adjusting the policy promptly. According to different evaluation participants, the policy evaluation can be divided into government evaluation, third-party evaluation, and other forms of evaluation. Based on contrast and comparison, the results

Table 14.11 Comparative analysis of policy evaluation of teachers' ICT capacity-building worldwide

Country	Government evaluation	Third-party evaluation	Other forms of evaluation
USA	✓	✖	✖
South Korea	✓	✖	✖
Singapore	✓ (since 2009)	✖	✖
Australia	✖	✓	✖
Britain	✓	✖	✖
China	✖	✖	✖

of the policy evaluation of teachers' ICT capacity-building worldwide are shown as below.

Table 14.11 shows that all countries pay much attention to the policy evaluation of teachers' ICT capacity-building. Through policy evaluation, the effectiveness of implementation can be summarized and problems can be identified, which helps to effectively adjust the formulation and implementation of the policy. As for the forms of policy evaluation, each country varies. In USA and South Korea, the government is responsible for evaluation, and South Korea's government has published the effectiveness of its ICT in education in the form of a white paper every year. However, Australia entrusts Dandolo partners (a renowned company to provide information service and creative suggestions for the government and private companies) to do the evaluation for 'Digital Education Revolution'. The Singapore government has taken up the policy evaluation since 2009.

14.4 Findings

After analyzing and comparing the relevant policies of different countries in the past 20 years, four main features presented in international policies for teachers' ICT capacity-building can be identified:

(1) Policies for teachers' ICT capacity-building have emphasized continuous design and steady advance in phases.
The international comparative study has indicated that the policies for teachers' ICT capacity-building have obvious features of stage, stability, and continuity, which plays an important role in promoting teachers' ICT competency continuously. According to the current status of teachers' ICT capacity-building in China, it is recommended that policies for future teachers' ICT capacity-building should be in accordance with the overall design of national ICT in education, keep on advancing steadily, insist on improving teachers' ICT competency and realizing ICT-enhanced transformation of

teaching, continue to implement the policies for teachers' ICT capacity-building actively, and adhere to the continuity and stability of macro policy for the improvement of relevance and coordination. According to the actual situation in different developmental stages of ICT in education, timely and appropriate adjustments are needed for steady progress at different stages.

(2) The goals of teachers' ICT capacity-building have evolved from technology literacy to knowledge deepening and finally to knowledge creation.
The primary feature of policy goals is the clarity. It is necessary to quantify the indicators of ICT capacity-building as much as possible, avoid all the indicators being qualitative, and the time and steps to realize policy goals should be clearly defined. In addition, the formulation of policy goals should be based on in-depth investigation of the actual situation; otherwise, it will suffer loss of practical significance. Analyzing the policy goals of teachers' ICT capacity-building in various countries, it is found that the developmental law of these goals is in accordance with the 'Knowledge Ladder Theory' proposed by Kozma (Kozma 2008). With continuing development of ICT in education, the goals of teachers' ICT capacity-building have moved from basic computer education to teachers' ICT skills, and then to ICT-enhanced transformation of teaching and learning, and finally to ICT-enhanced knowledge innovation. In the future, Chinese policy goals should focus on the change from knowledge deepening to knowledge creation, and the integration of information technology into teaching as well. Meanwhile, because of the regional differences in ICT in education in China, the actual situation of different schools or regions should be taken into consideration when policy goals are made.

(3) All countries have attached importance to enacting supporting policies to provide guarantee for implementing the policies for teachers' ICT capacity-building.
Each country has introduced supporting policies to ensure the implementation of the policies for teachers' ICT capacity-building. Three main forms have been worked out: first, the execution of the policy can be strengthened through legislation, and when necessary, actions could be taken for persons who impede the execution of the policy. Second, the rules can be formulated to guide the implementation of the policy based on expert survey. Next, corresponding incentive mechanisms should be established to direct and encourage teachers, school principals, district educational departments, and companies to participate in teachers' ICT capacity-building actively. Finally, a multidimensional policy system can be formed with the help of the supporting policies, and various forces can be mobilized to create a good environment for teachers' ICT capacity-building.

(4) Each country has emphasized the policy evaluation of teachers' ICT capacity-building.

The evaluation of teachers' ICT capacity-building is an activity that combines training evaluation, project evaluation with performance evaluation. It includes data collection and value judgment for training project from project design, project implementation, to project effectiveness and provides guidance to subsequent phases of the project and improvement of the whole project. The evaluation of teacher training project is mainly organized by the administrative department of education, and its main purpose lies in promoting the effectiveness of the work. The evaluation staff is composed of project management officials, supplemented by evaluation experts. The main mechanism to evaluate concludes the evaluation of tenders, standards matched acceptance, and so on. The evaluation has not had a perfect system, as many training activities are just for the sake of discussion, and have no ongoing follow-up to teachers' teaching after training. Thereby, it is recommended that third-party evaluation institutions should be established to evaluate the teacher training project promoted by the government, which can support schools' self-improvement and government's review and then ensure the effectiveness of teacher training.

14.5 Conclusions

Based on the policy review of teachers' ICT capacity-building in USA, Britain, South Korea, Singapore, Australia, and China through comparative study, it is concluded that in the future four aspects need to be improved in terms of the formulation, implementation, and evaluation of the policy for teachers' ICT capacity-building in China.

(1) The continuous design of the policy is of importance. The policy should be guaranteed to keep good connection both in horizontal and vertical orientations and be promoted steadily according to different stages in different regions.
(2) Technology literacy, knowledge deepening, and knowledge creation should be treated as the main policy goals in different stages to gradually improve teachers' ICT competency and then promote the development of ICT in education.
(3) Supporting policies should be enacted to ensure that the policy goals can be achieved smoothly.
(4) The evaluation of the effectiveness of teachers' ICT capacity-building should be strengthened. Third-party evaluation can be introduced to identify problems and deficiencies in policies, and then the policies can be adjusted promptly to maintain a healthy, sustainable, and stable development of teachers' ICT capacity-building.

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