Perspectives on Rethinking and Reforming Education

Shengquan Yu
Hannele Niemi
Jon Mason *Editors*

Shaping Future Schools with Digital Technology

An International Handbook

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Perspectives on Rethinking and Reforming Education

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Preface

When we talk about the future, it's not limited to a concept of time. The future is not only the place we are going but also the place we want to create. From an educational perspective, conceiving of the future stimulates expectation, desiring improvement, educational reform, and educational modernization. Future education asks for innovation, for renovation, and for development. As John Dewey remarked, *if we teach today as we taught yesterday, then we rob our children of tomorrow*. The future in the view of education is beyond the concept of time. Future education has an exceeding demand for change. It might manifest in a diversity of forms but toward an affirmative direction and rationale of development. The development of new technology will make significant structural changes in future education, enabling real ubiquitous learning. The instructional environment, the learning patterns, and the fundamental components of schools will change. The school's operating mode, rules, and culture will change, and the structure and form will be reorganized. In this restructuring process, the following trends are prominent:

First of all, future education should consider the individualization and diversity of students. To meet the demand of personal development of all students by considering the differences in their innate and acquired growth, it's a great value to offer them the most suitable educational services suited to their level. Einstein has once declared: *Everybody is a Genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid*. Future education will fully consider the personality and development of each student. With the effective and wise use of AI technology we can surpass the personalized and small-scale education of the agricultural society, we can surpass the non-personalized and large-scale education of the industrialized society, and we can then establish a personalized but large-scaled educational system.

There are three core keywords associated with future education: personalization, adaptability, and selectivity. Students in the future will not have to follow a fixed curriculum, sit in a fixed class, and learn in a fixed rhythm. New technology can accurately judge the learner's cognition, capability, and emotion so as to present strategies and methods most fit for a learner. The school supported by online education will provide learners with more choices to choose most suitable personalized education.

Establishing an educational system on the basis of big data and artificial intelligence is an inevitable trend for future schools. The current one-size-fits-all model will be changed. In the future, massive learning data collection and analysis will enable accurate images of characteristics of each student. Online and offline blended, personalized, and selectable learning spaces can be set up to recommend precise knowledge, learning data, learning content, learning activities, and learning specialists for learners or educators. With them, formative evaluation will be flexible enough to support adaptability and selectivity of learning.

Second, future education can promote all-round development of learners. The future society is positioned to be a highly intelligent society. Menial mental tasks will soon be replaced by AI machines. People in the future need to develop higher order thinking skills, and to cultivate compassion and sympathy, with deep insight, wide wisdom, and high responsibility for both oneself and others.

At present, data, information, and knowledge are accelerating at a rate that has doubled every few years. This presents a challenge for us to likewise develop our learning and cognitive abilities. A single person's intelligence is of course limited. But with the help of mobile Internet, computers, and artificial intelligence, we can process huge amount of information and data and promote our ability to handle emergencies and complexities. Thinking with the aid of technology can break through the limits of human cognition and cope with the rapid changes of the world that transcend individual cognitive abilities.

The future teacher supported by big data and artificial intelligence will change greatly. Knowledge and skills delivery will be dramatically supplemented by artificial intelligence while other aspects of educating and cultivating become more and more important. New technology will save teachers' time and help them care more for the students' soul, spirit, and happiness since there would be time for them to have further communication with students, to inspire students for more motivation and interest to do more creative and innovative learning. Future education will enter the era of co-working between teachers and artificial intelligence. Teachers and artificial intelligence will highlight their respective advantages to achieve better personalized, inclusive, fair, and lifelong learning.

Third, future education is lifelong and comprehensive learning in real life. In the future school, learning, work, and life are all-in-one. Learning is more than just acquiring a certain knowledge or skill, it includes the growth of the whole person. Education provides a ladder of opportunity for all people to perceive the beauty of the world. Other than a means of making a living, education enlightens our whole being, assists the growth of our thinking, and can boost the spiritual happiness for all society. Education in the future will continue to loosen the boundary constraints of time and space. That anybody can learn anytime anywhere through any digital environment to access any knowledge and information comes true. Learning anytime anywhere will occur on demand and increasingly self-regulated, supported by technology appropriate to the context of organization, representation, and service.

Fourth, future education will be increasingly social. Education relying on Internet could realistically become an integral part of school education. Good quality learning resources and educational services do not necessarily come from one single school. Learning services are sharply expanding and learning activities conducted by individuals or institutions outside schools are becoming more prevalent. The core elements of the entire educational system will be reorganized and restructured. Learners, content providers, educators, stakeholders, testing service, and certificate providers may come from different social institutions, nonprofit organizations, specialized research institutes, and Ed-Tech companies.

The walls of the traditional school are being dismantled. More and more learning services from professional institutions will emerge. In the future, students and parents can freely choose educational services from schools or from the Internet, which offers personalized learning that aligns with individual personality, interests, and parents' goals and values. Students can select and self-organize their own learning services across the school boundaries among various learning services, under the circumstance of accurate learning data being fully mastered.

In this book, we collect and compile several ongoing projects and research about future schools and education to illuminate the current and potential development of learning. We imagine an outlook of future education in 2030 and observe the technology-enhanced learning in different countries toward the development of future education—Smart Learning, Active Learning, Intelligent Learning, STEM learning, Game-based Learning, and Mobile Learning supported by latest technology are inclusive in the collection of chapters. As well as technology, however, is commentary on psychology, pedagogy, and experience of Ed-tech in learning that also sheds light on our way to future education. We wish this book will be of benefit to researchers, teachers, learners, stakeholders, technicians, practitioners, and learning service providers who are also aiming for a bright future of education.

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Chapter 1
The Future of Education: 2030

Yong Zhao

1.1 Introduction

Future Schools can have two different yet related interpretations: “the future of schools,” or “schools in the future.” Discussions about the former, the future of schools, are more concerned about what the future holds for today’s schools. They would primarily focus on the fate of schools: will they change, will they continue to exist, and what, if anything, they need to do in order to exist? Discussions about the latter, schools in the future, assume that schools will continue to exist in the future, although they may operate differently. They would be mainly interested in questions such as what future schools would look like, would or should they be different from today’s schools, and if so, how different they will or should be from today’s schools.

Schools are established to provide education. In other words, schools exist because of education, not the other way around. Thus, any discussion about the future of schools or schools in the future must start with discussions about the future of education. Education will always exist, but schools may not. It is quite possible that education in the future does not need schools or entirely different types of organizations from today’s schools. It is also possible that in the future, schools would have been transformed so much that a new name should be used to replace “schools.”

Therefore, although the title of this article is *Future Schools*, the focus of the discussion is the future of education. It is, of course, presumptuous for anyone to talk about *the* future of education because there is not and cannot be just one future. Instead, there are many possible futures. Different people can envision different futures of education. Hence what is presented here is only *a*, rather than *the*, future of education.

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1.2 Defining the Future: Forecast Versus Designed

When preparing or planning for the future, two ways of thinking are prominent: forecasting and designing. One is to forecast the future like a meteorologist predicts the weather conditions tomorrow. It is a noninterventionist approach that makes the forecast based on available evidence and theory of change without taking any actions to affect the course of change. This approach attempts to answer the question “what will education be in the future?” The resulting answer may vary from one forecaster to another, depending on their interpretation of the evidence and theoretical framework. The accuracy of the prediction varies as well. But one thing does not change and, that is, the futurist taking this approach does not have a vested interest in the answer. He or she tells what it will likely be, instead of what it should be.

The other way to think about education is interventionist. It focuses on what the future should be instead of what it will be. In other words, the futurist here is not an objective forecaster, but a visionary, a designer, an architect, or a creator. He or she is deeply committed to one future over other possible futures. Moreover, he or she is willing to take actions to promote and actualize his or her desired future, in other words, to design the future.

While the two approaches are fundamentally different in terms of whether the futurist’s role in the resulting future, both need to respect evidence and be consistent with sound theories. To design a future is not the same as fantasizing. As much as the designer wishes for a future, the future must be rooted in reality and reasonably achievable in the future.

The version of the future presented here is a designed one. It is not a prediction, but a hope, a vision. It is what education should be and can be but it requires efforts and actions. In other words, this vision of education is not a guaranteed reality in the future. However, it is not wishful thinking either. It is achievable.

It is also critical to set a time frame when thinking about the future. Any time after the present moment is the future. Tomorrow is the future, so is next month, year, century or millennium. The future discussed here is the year 2030, about a decade hence. Although the exact year 2030 is an arbitrary decision, the time frame of about 10–15 years is not. It is decided for a number of reasons. First, education, as a cultural and social institution, cannot be changed overnight. Educational changes are always evolutionary, although the expected outcome may be revolutionary. So, it is unreasonable to expect widespread significant changes in less than 10 years. Second, education is fundamentally about preparing young generations who will create a more positive future for all humans. Given the rapidity of societal changes, education must change fast in order to help humanity meet the challenges of these changes. The urgency of change cannot wait for too long into the future.

1.3 Defining Education

Before imagining the future of education, a clear definition of education is in order. As a commonly used word, education has acquired many different meanings in different contexts, for different people, and in different cultures. For example, the *Oxford Dictionary of English*, defines education as "a process of teaching, training and learning," "a particular kind of teaching or training," "the institutions or people involved in teaching and training," and "the subject of study that deals with how to teach."

For discussions of the future of education, it is necessary to consider the entire spectrum of possible definitions of the word because the various meanings are inherently integrated and dependent upon each other. The primary meaning of education focuses on the process of teaching and learning. To enable the process, modern societies have developed education into a formalized institution. There are typically more than institutions that serve the function of education in a given society, which then forms a system. The prominence and continuity of education in most modern societies have made it a cultural phenomenon and tool, defining and being defined by the culture within which it is located. Thus, education is defined as a process, an institution, a system, and a cultural phenomenon that intends to prepare future generations to become fully functional members of a society.

1.4 Factors Shaping the Future

Many factors affect education and shape its future. Some of the factors influence the formation of education as an institution, and some its operations. Some factors affect the organization of education as a system, and some affect the process of education. Some factors influence the culture of education, and some affect the purpose and outcomes of education.

Factors affecting the future of education are both internal and external. Internal factors are variables within the education system and institutions such as existing policies, curriculum, and personnel. Students, teachers, and education leaders are major players within education, who have significant influence over the future of education. They also include industries that seek to benefit from education by providing products and services such as textbook publishers and educational technology companies. External forces are outside the education system such as culture and society. Politicians, parents, businesses, and the general public are important external players, who can exert tremendous influence on education.

To design an achievable vision of the future of education requires a thorough understanding of both external and internal forces affecting education. This understanding should be built on current knowledge and evidence and follows a reasonable chain of logic. Below is a discussion of current understandings of major factors that can have a significant impact on the future of education.

1.4.1 Technology

Technology is "the application of scientific knowledge for practical purposes," according to the Oxford Dictionary of English. It is not limited to information and communication technology, as often considered in the field of educational technology today. In the discussion about the future of education, technology refers to all applications of scientific knowledge for practical purposes in human societies because they all have an impact on education.

Technology affects education in two important ways. First, it redefines the value of knowledge and abilities. Education is supposed to equip students with valuable knowledge and abilities. Thus, by redefining the value of knowledge and abilities, technology can fundamentally redefine the outcomes of education, that is, what education should be about. Second, it affects how education should be delivered, conducted, and operated. A significant part of education involves information and communication. As information and communication technology advances, it provides great potential to change the education process by affecting how information transmission and communication are conducted. When the process is affected, so are the operations and organizations of education.

1.4.2 Redefining Outcomes

Education runs a race against technology (Goldin & Katz, 2008). Technology, in its essence, is about enhancing human capabilities. For example, television is to enhance human capabilities to view happenings that are beyond their natural vision and hearing, so is a telescope. The steam engine enhanced human capacities to manipulate energy and move objects beyond the natural strength of human beings. While enhancing human capabilities, technology renders some capabilities less valuable and others more important. For example, the arrival of steam engines and other forms of transportation not only made it possible for human beings to transport more objects over longer distance, but also rendered knowledge and skills in advancing, operating, and maintaining engines more valuable while decrease the value of knowledge and skills in building and maintaining horse wagons or manufacturing sails for ships.

Education is supposed to help human beings learn knowledge and skills that are valuable for success in life (Spencer, 1911). Since it is impossible for humans to master all knowledge and skills, educational institutions must teach knowledge and skills that are of the most worth, as the British philosopher Herbert Spencer argued in his essay published over 150 years ago. Thus, educational institutions must constantly evaluate what they teach or attempt to cultivate in future citizens. When education can equip the masses with the skills and knowledge deemed valuable by society, the potential prosperity brought about by technology is shared across society. Otherwise, human societies suffer from large prosperity gaps—with a few enjoy tremendous wealth, while the rest live in poverty.

Humans have gone through numerous major technological revolutions that have transformed societies and drastically redefined the value of knowledge and skills. Education has been able to catch up to the aftermath of the First and Second Industrial Revolutions, although it took decades to do so. The education currently in operation in many countries is the result of responding to the changes brought about by the First and Second Industrial Revolutions. This education successfully equipped a massive number of people with the knowledge and skills needed in the industrial society and thus ushered in an era of economic prosperity after World War II in many countries around the world. In other words, education caught up to technological changes.

However, technology advances do not stop. Over the past few decades, technology has advanced again, in revolutionary ways. The accumulation of technological changes has amounted to the so-called Third Industrial Revolution characterized by automation, which has led to the decline of many traditional industries such as manufacturing (Florida, 2012; Schwab, 2015). Moreover, the revolution continues. As a result, humans are entering the Second Machine Age or the Fourth Industrial Revolution characterized by Artificial Intelligence (AI) and universal connectedness, which are predicated to transform human societies in drastic ways (Brynjolfsson & McAfee, 2014; Ross, 2016; Schwab, 2015).

This revolution is again redefining the value of knowledge and abilities. The knowledge and skills needed for the industrial society have been losing value or become obsolete because the tasks that required those knowledge and skills have been increasingly performed by technology (Brynjolfsson & McAfee, 2014; Ross, 2016; Schwab, 2015; Zhao, 2012, 2015). Harvard economists Claudia Goldin and Lawrence Katz write:

> Today skills, no matter how complex, that can be exported through outsourcing or offshoring are vulnerable. Even some highly skilled jobs that can be outsourced, such as reading radiographs, may be in danger of having stable or declining demand. Skills for which a computer program can substitute are also in danger. But skills for non-routine employments and jobs with in-person skills are less susceptible (Goldin & Katz, 2008, p. 352).

In the meantime, new technologies have created new opportunities, which make traditionally undervalued knowledge, skills, and abilities gain more value (Pink, 2006; Trilling & Fadel, 2009; Wagner, 2008, 2012; Zhao, 2009, 2012, 2015). For example, American author Daniel Pink suggests that the traditionally valued "Left-brain skills" are increasingly losing value but "the capabilities we once distained or thought frivolous—the 'right brain' qualities of inventiveness, empathy, joyfulness, and meaning—increasingly will determine who flourishes and who flounders" (Pink, 2006, p. 3).

In order to prepare citizens to meet the challenges and take advantage of the opportunities of this round of technological advances, education must rethink the knowledge, skills, and abilities it aims to cultivate. There have been many efforts around the world to redefine the valuable knowledge and skills (Zhao, 2016a). One of the most widely known efforts is from the Partnership for 21st Century Skills, a partnership organization with members from national education organizations, major businesses, and educational institutions founded in 2002. The organization believes that "every child in America needs 21st century knowledge and skills to succeed as effective citizens, workers and leaders in the 21st century" (Partnership for 21st Century Skills, 2008). "[T]he skills, knowledge and expertise students should master to succeed in work and life in the 21st century." The Partnership describes in its *Framework for 21st Century Learning* 21st (Partnership for 21st Century Skills, 2007) are *core subjects* such as English, math, history, and *21st Century themes* such as global awareness, entrepreneurial literacy and health literacy, *Learning and Innovation Skills* that include creativity and innovation skills, critical thinking and problem-solving skills, communication and collaboration skill*s*, *Information, Media and Technology Skills* such as information literacy and media literacy, and *Life and Career Skills* that include flexibility and adaptability, initiative and self-direction, social and cross-cultural skills, productivity and accountability, leadership and responsibility.

The European Union has also engaged in similar efforts, although they did not use the phrase "21st Century Skills." The European Parliament and the Council of European Union, the highest governing bodies of the European Union, have worked to "identify and define the key competences necessary for personal fulfillment, active citizenship, social cohesion and employability in a knowledge society." Their efforts resulted in eight key competencies that all European citizens are believed to need in order to "adapt flexibly to a rapidly changing and highly interconnected world" (The European Parliament & The Council of the European Union, 2006). Competencies are "a combination of knowledge, skills and attitudes appropriate to the context." The eight key competencies are communication in the mother tongue, communication in foreign languages, mathematical competence and basic competences in science and technology, digital competence, learning to learn, social and civic competences, sense of initiative and entrepreneurship, and cultural awareness and expression.

Although these efforts were started first in Western-developed countries that experienced the impact of this round of technological changes first, the need to do so is worldwide. In a globalized economy, no society is immune to the impact of technology. Machines displacing humans is not isolated to developed countries. It is a global phenomenon. Education in the future must equip human beings with knowledge and skills and abilities that cannot be replaced by machines, no matter how intelligent machines may become.

The only way humans can compete with machines is not to become machines. In other words, humans must be able to do things machines cannot do. But traditional education has been about turning humans into machines—identical devices with similar capabilities to perform tasks predefined by humans with no social or emotional involvement. The education we need is to make humans more human—unique, diverse, creative, entrepreneurial, social, and emotional.

1.5 Redefining the Arrangement

All educational activities involve some sorts of information exchange. The exchange can happen among learners, between learners and teachers (masters), or between learners and other sources of information or expertise such as books, videos, or audio recordings. Educational arrangement is in essence about establishing ways to facilitate the process of information exchange.

Historically, the information exchange is often between individuals with more knowledge and expertise (teachers) and those with less (students). Up until recently, teachers have been the primary and in some cases the sole source of information. Thus, the arrangement has typically been placing teachers in the same physical location as learners. To make the process more efficient, one teacher is often assigned to a group of students, which forms a class. Because the traditional education model is about transmitting the same set of knowledge and cultivate a homogenous set of skills in all students, the most efficient way for *one* teacher to teach a group of students seems to be grouping students based on their level of abilities. And the most convenient way to do so is based on the age of the students based on the assumption, rightly or wrongly, that children at the same biological age have similar abilities or know about the same amount. In some cases, those children who are significantly below or above the average of their peers are retained a grade or put into other programs for remediation or acceleration.

Information and communication technology can greatly affect this arrangement. Information and communication technologies have advanced so much that students now have ubiquitous access to experts and content beyond their immediate classrooms. Besides the generic content widely available on the Internet, a vast amount of content aligned with school curriculum and presented by expert instructors has become available for little or no cost. These content materials are accessible at the fingertips of students and they can often be more relevant, more engaging, more personalizable, and more on-demand than what typically is provided by teachers in classrooms (Bergmann & Sams, 2012; Bonk, 2011; Khan, 2012; Mitra, 2012). Likewise, students can access content experts, tutors, and fellow learners through social media and other forms of rich media communication tools such as Google Hangouts and Skype. Research shows no significant difference in academic learning outcomes between online and face-to-face instruction (Russell, 2003; Zhao, Lei, Yan, Lai, & Tan, 2005).

Moreover, research suggests children are capable of self-organizing their learning without being directly instructed by an adult (Elmore, 2011; Mitra, 2012). Children are naturally born learners (Smilkstein, 2011). They are motivated and are able to learn on their own, given the opportunities and materials (Bransford, Brown, & Cocking, 2000; Gopnik, Meltzoff, & Kuhl, 1999; Meltzoff, 1999; Smilkstein, 2011).

In fact, research suggests that children learn more effectively without being directly or explicitly instructed. They learn from their peers through collaborative learning (Dillenbourg, 1999; Hamada, 2014; Hmelo-Silver, 2013). They learn by doing through authentic project-based learning (Bailey, 2016; Dewey, 1938, 1998;

Diffily & Sassman, 2002; Thomas, 2000). They construct knowledge, test hypotheses, and formulate new ideas through exploring and experimenting socially and individually (Bransford et al., 2000; Harel & Papert, 1991; Papert, 1993; Piaget, 1957).

Thus, we can reimagine very different ways to arrange educational activities. Perhaps, teachers no longer need to instruct. Instead, they organize and support. Perhaps we no longer need to group students into age-based classes. Perhaps students no longer need to come to school or class. Perhaps schools no longer need to have one physical location. The possibility for rearranging educational process and activities is endless.

1.5.1 Diversity: Human Nature

As a species, human beings have enough commonalities that distinguish them from other species. But within the human species, each individual member is unique. The uniqueness comes from both nature and nurture. Human beings are not born a blank slate or exactly the same and their experiences after birth vary as well. The interactions between innate variations and experiential differences or nature via nurture result in unique individuals who are drastically different from each other on many dimensions (Ridley, 2003).

Human differences exist in a multitude of areas. The differences in some areas are much more obvious than others. Physical appearances, for example, are much more visible than intellectual abilities. We can directly see physical differences such as gender, hair color, height, weight, length of arms, and many other aspects of physicality. But intellectual abilities can only be "seen" indirectly.

Psychometrics has been developed to "see" the visible qualities of human beings (Kaplan, 2016). Decades of efforts have produced a large body of theoretical frameworks and empirical evidence to show individual differences in a number of areas. Although there are plenty of controversies over many technical details and specific theories, there is a consensus that human beings indeed vary in aptitude, personality, motivation, knowledge and skills, values and beliefs, attitudes, mindset, and other psychological aspects.

Humans differ in their aptitude, a natural born capacity for learning. Although Howard Garner's Multiple Intelligences Theory (Gardner, 1983) has met with criticism for different reasons, the idea that human beings are born with different natural abilities and potentials is widely accepted and observed. According to Gardner, some are born to be more sensitive to languages, while others in math. Some are natural learners of visual arts while others are more talented in music.

Human beings also have different patterns of thinking, feeling, and behaving or "personalities" (John, Robins, & Pervin, 2008). Personality researchers have over the past several decades proposed various models and theories about human personalities. One of the more accepted theories is the Big-Five Model (McCrae & Terracciano, 2005), which suggests human personalities differ along five dimensions: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. In other words, some people are more open to new experiences, while others may be more cautious with adventures. Similarly, some people have the tendency to be more organized and dependable other others. Likewise, some are more outgoing than others, while some are friendlier than others.

People also differ in their desires or motivation, an aspect of personality. Psychologist Stephen Reiss proposes 16 basic human motivators but each person has a different motivational profile (Reiss, 2000, 2004). Reiss suggests an individual would have strong or weak desires in pursuing one of the 16 needs: acceptance, curiosity, eating, family, honor, idealism, independence, order, physical activity, power, romance, saving, social contact, social status, tranquility, and vengeance. In other words, some people may be extremely driven by achieving social status, while others may not even care about their social standings. Similarly, some people have a strong desire for orderliness while others can put up with a very messy closet.

There are other areas in which humans can vary. They can have more or less knowledge in certain domains or be more or less skilled with certain tasks. For example, some people may know more about U.S. history but know very little about dinosaurs. One can be very good at playing basketball while being horrible at playing the piano. By the same token, some people are extremely skilled at carpentry but is not a very good dancer.

There is no doubt that we still do not know all about the complex human beings, but what we know for sure is that each and every one of us is unique. Not only are we unique in one area, but also in the combination of all the areas. In fact, when we combine the variations in all domains that human beings can vary, each member of the species differs even more from each other. Everyone has a “jagged profile” (Rose, 2016) or a unique combination of strengths and weaknesses: stronger in some areas and weaker in others.

1.6 Redefining Educational Outcomes

The knowledge of human nature as diverse and unique individuals can help us rethink educational outcomes. The basic question is: should we enhance their strengths or fix their deficits? In other words, given that each individual student has strengths and weaknesses, is it more desirable to make sure that we help mend their weakness so they can meet some predetermined standards, reach prescribed level of competency, and be just like others or is it more important to allow them to escape their weaknesses and instead focusing enhancing their strengths?

In the Industrial Age, when education is about instilling a homogenous set of skills and knowledge into all students, individual uniqueness is a tremendous inconvenience and interference. Individual strengths are considered unimportant compared to what is prescribed in curricula or standardized tests. Every student is judged on their mastery of the required content and skills based on prescribed standards regardless of their strengths and weaknesses because what is prescribed, not what each student possesses, is considered important. When students are deemed, often by standardized tests, to be behind, they are to be fixed, ignoring their strengths or passions.

It is possible that we have arrived at a time when individual uniqueness needs to be promoted. As discussed previously, in the Age of Smart Machines, the only way for humans to compete with machines is not to become machines. Instead, they should become more human. Diversity and uniqueness are what differentiate humans from machines. So, education in the future should perhaps work on enhancing individual strengths instead of fixing their deficits. Could we have an education that does not have to impose on all children the same knowledge and skills? Instead, we can have an education that values individual uniqueness and helps each individual student to be the best he or she can be?

1.7 Redefining Arrangement

The fact that human beings are unique and diverse also affects the delivery of education. Humans are different but they are expected to become the same through schooling. Thus, schools have been tasked with the responsibility to come up with various ways to help all students move along the same pathway at the same speed, including accountability measures for schools and teachers with the belief that all students are willing and able to learn the same thing at the same speed. Other interventions include remediation courses and programs such as special education and accelerated programs such as talented and gifted programs, as a way to ensure students in the same group are of similar abilities.

Having recognized the existence of individual differences, education has started to personalize or individualize learning for all students, especially with the help of technology. From Skinnerian Programmed Learning to big-data-driven artificial intelligence supported personalized learning systems today, schools have been working on different ways to enable each individual student can learn at their own speed following their own preferred learning styles. This trend will continue and the availability of resources and emerging personalized learning tools will significantly affect how schools are to be organized and how learning is delivered in the future. When individual students can create their own individual learning pathways from anywhere, anytime, and from anyone, the traditional definition of teachers, classrooms, and schools would change significantly.

1.8 Knowledge About Human Learning

Knowledge about how humans learn new things affects the design of education. Regardless of the outcomes, all education entities wish to find the most effective way to help children learn what they are supposed to learn. Research in learning sciences, psychology, neurosciences, and education over past few decades has provided evidence that it is reasonable to believe that human beings are not born a blank slate to be carved on or an empty vessel to be filled in with knowledge. Cognitive scientists such as Steven Pinker of Harvard University have brought evidence to support that human beings are not born a "blank slate" waiting to be carved by experiences and teachers (Cziko, 1995; Pinker, 2003). Children have certain innate propensities for developing and learning that must be respected. Psychologists such as Howard Gardner of Harvard University (Gardner, 1983) and Robert Stenberg, formerly of Yale University (Sternberg, 1985) have challenged the traditional narrow view of human intelligence and postulated that human beings are talented in different areas, further supporting the proposition that each child is unique and must be treated differently.

Furthermore, starting with works of the Swiss developmental psychologist Jean Piaget and the Russian psychologist Lev Vygotsky, last century saw a "constructivism" revolution in learning theory, which significantly altered the traditional view of the learner and the learning process. Constructivist psychologists have brought abundant evidence to show that children are unique learners with unique needs and backgrounds and actively construct knowledge based on their previous experiences instead of passively receiving it (Glasersfeld, 1989). Learning is not the development of superficial links between stimulus and response or conditioning specific behaviors, as behaviorist psychologists used to believe. Learners create hypotheses and test them in life. They then retain the hypotheses that work and discard ones that don't. Upon which, they create news and test them again. This process is akin to the evolutionary of species—the fittest hypothesis survives (Cziko, 1995).

While disagreements regarding the specifics exist today, it is generally agreed among cognitive scientists and educational researchers (Bransford et al., 2000) that children:

- Are born with curiosity and the ability to learn.
- Are not born with exactly the same capacities for learning the same things.
- Come to school with different levels of cognitive, emotional, physical, and social development due to a combination of nature and nurture.
- Come to school with different needs, interests, and different abilities.
- Are active learners with unique needs.
- Should bear the responsibility of learning.
- Learn best when intrinsically motived.
- Are motivated when respected, encouraged, and exposed to opportunities that capture their interest, build on their previous experience, and recognized for their accomplishment.

Thus, education must be designed around the child and be child-centered. A good education should aim to meet each child's unique needs, capitalize on each child's strengths, and grant the child autonomy so he or she can take the responsibility for learning.

1.9 Problems with the Traditional Education Paradigm

Thinking about the future requires knowing the past and present, particularly the problems with education in the past and present because hopefully, education in the future can solve the problems. There are three significant problems that have been identified with education today: obsolescence, student disengagement, and inequality.

First, education is no longer adequate to prepare children for the changed world that will continue to change rapidly (Barber, Donnelly, & Rizvi, 2012; Trilling & Fadel, 2009; Wagner, 2008, 2012; Zhao, 2012, 2015). Technological changes have already led to the disappearance of millions of jobs used to be held by humans, resulting in massive unemployment and underemployment, especially among youth. Youth unemployment and underemployment have become a crisis in many countries, both developed and developing (Allen, 2011; Elliot, 2013; Mbele, 2013; Organization for Economic Cooperation and Development [OECD], 2011; Provost, 2011; Salmon, 2011; The Economist, 2011; Zhao, 2015). Education has traditionally been believed to be the institution to prepare youth for gainful employment. But it does not seem to do that anymore. In the U.S. and other developed nations, even a college education no longer guarantees a good job (Abel, Deitz, & Su, 2014; Deitz, & Abel 2016; Kroeger, Cooke, & Gould, 2016). For example, in the U.S., the Gallup Daily Poll found that in June 2017, only about 45% of adults reported having "a good job," defined as "30+ hours per week for an employer who provides a regular paycheck. Good jobs are essential to a thriving economy, a growing middle class, a booming entrepreneurial sector and, most importantly, human development" (Gallup, 2017). Chinese college graduates have been having a difficult time finding "good" jobs as well.[1]

The second problem is that student disengagement and mental health. According to a longitudinal survey of over 350,000 high school students in 40 states in the United States, only 2% reported never being bored in school. Two out of three (66%) students reported being bored at least every day in class in high school (Yazzie-Mintz, 2010). The annual Gallup Student Poll reported that 29% of students in the U.S. were "not engaged" in 2016 and 22% were "actively disengaged"(Gallup Student Poll, 2016). Although there is no readily available data about student engagement in China, education in China and other Eastern Asian nations does seem to result in students experiencing high anxiety, pressure, low confidence, and a loss of interest in the subjects (Cheng, 2011; Jiang, 2010; Zhao, 2014).

The third problem that is common to almost all education systems around the world is equity or lack thereof. It is a well-known fact that the quality of education children experience around the world varies a great deal from country to country and from school to school within countries. The difference in educational quality does not have anything to do with the children but with where they happen to be born and their parents. Children born into wealthy communities and with well-to-do

[1] http://news.sina.com.cn/pl/2017-03-09/doc-ifychhuq3373946.shtml.

parents generally, receive higher quality education their peers in poor communities and families.

There is also another type of inequality or active discrimination in education that result from the differences of children themselves. As mentioned previously, children are unique and different from each other. But education, as practiced today, seeks homogenization and only values certain types of students—typically those who happen to be good at school subjects and willing to be homogenized. As a result, students with talents and interest beyond the school subjects are not provided the educational opportunities to develop their talents and interest. Worse yet, they are actively discriminated against and often excluded from seeking better education beyond compulsory education because they cannot pass the required exams.

1.10 The Future of Education: A Paradigm Shift

Taking into consideration the total impact of all the factors affecting the future of education, it is reasonable to believe the education in the future and for the future should be and can be drastically different from the education in the past and at present. The changes needed cannot be a small improvement but a complete transformation, a paradigm shift (Kuhn, 1996). The existing paradigm can no longer address the challenges today and in the future.

The existing education paradigm aims to prepare individuals to find gainful employment in the current economy and to fit into the existing society. It was designed to produce workers for the mass-production economy that came with the Industrial Revolution. The mass-production economy needed a large workforce with similar skills and knowledge, but at very basic levels. To educate the masses with similar basic knowledge and skills requires a paradigm characterized by a common curriculum, a pedagogical approach designed to deliver the prescribed curriculum, and a setting in which the delivery is most efficiently completed. As a result, the existing education attempts to teach the same knowledge and skills to all students and expect all students to learn the same knowledge and skills at the same speed regardless of their talents or interests.

But as discussed previously, the world today is no longer the world of mass production. It no longer values basic skills and knowledge or homogeneous individuals. In other words, the existing education paradigm aims to prepare children for a society that no longer exists. The students it graduates are not needed today, let alone in the future, as evidenced by the employment situation in the world.

Furthermore, the existing paradigm functions as sorting mechanism in a so-called meritocracy (Zhao, 2016b). It appropriates resources and opportunities based on a narrowly predefined "merit," namely academic performances in schools. Students who happen to be good at school subjects and are willing to do whatever schools require them to do are considered to have the merit and thus celebrated and granted opportunities, while those who may be talented and interested in other areas are considered deficient, needing remediation, and excluded from certain opportunities. This is the cause of disengagement and a source of discrimination based on talents.

To meet the challenges of the future and address current problems in education, we need a new paradigm. The new paradigm should not presuppose or predefine what knowledge or skills are worthwhile. In this paradigm, the "curriculum" is one that follows the child. It begins with the children: what they are interested in, what excites them, what they are capable of, and how they learn. This paradigm does not assume all children are the same; therefore, it does not impose artificial standards or age-based, grade-level expectations. It helps children move forward from where they are. Furthermore, it does not believe children are simply empty vessels ready to be filled with knowledge, but rather it assumes that each child is a purposeful agent who actively interacts with the outside world.

The great American educator and philosopher John Dewey summarizes the differences between the two paradigms almost 80 years ago in his *Education and Experience:*

> To imposition from above is opposed expression and cultivation of individuality; to external discipline is opposed free activity; to learning from texts and teachers, learning through experience; to acquisition of isolated skills and techniques by drill, is opposed acquisition of them as means of attaining ends which make direct vital appeal; to preparation for a more or less remote future is opposed making the most of the opportunities of present life; to static aims and materials is opposed acquaintance with a changing world (Dewey, 1938, 1998, pp. 5–6).

Specifically, the proposed new paradigm of education in the future will differ from the existing one significantly in three fundamental aspects of education: what to learn, how to learn, and where to learn. All education must be concerned with these three aspects. What to learn is about the curriculum, which is dictated by the outcomes and purpose of education. How to learn is the delivery or arrangement of education that helps students learn what they need to learn. Where to learn is the environment in which learning occurs.

1.11 Autonomy and Personalized Education: The New What

In contrast to the existing paradigm that imposes the same prescribed curriculum for all students, the new one grants student maximum autonomy and agency in defining what they want to learn. The curriculum follows and supports the children's passions and enhances their strengths instead of fixing their deficit. Supporting and enhancing students' unique passion and strength through personalized education is necessary to produce the kind of talents needed in the future: creative, entrepreneurial, and globally minded and capable citizens for the following reasons.

1.11.1 Unique and Diverse Talents

In a globalized world crowded by more than seven billion individuals, we cannot all have the same talent and compete for the same job. Likewise, in a world where human needs are diverse, a standardized set of talents cannot possibly meet all the needs. Furthermore, in a world that is changing constantly and rapidly, a predetermined set of standardized skills and talents are not good bets for jobs that have not yet been invented. Moreover, in the age of Smart Machines when technology can perform repetitive and identical tasks more efficiently than human beings, humans are best at unique tasks that require entrepreneurial thinking and creativity. More important, in a world where human interests, backgrounds, living conditions, and abilities are diverse, it is ethically wrong and economically disastrous to reduce all the diversity into a few skills. Granting and supporting individual students' pursuit of learning enables the development of unique and diverse talents.

1.11.2 From Adequate to Great

While the agricultural and mass-production industrial economy needs many workers with similar skills, these skills are routine, standard, and basic. As technology and economic globalization render the traditional lines of jobs obsolete and the economy is increasingly driven by knowledge and creativity (Florida, 2002; Goldin & Katz, 2008), we will need individuals with different talents and skills—but beyond what can be standardized and basic. They need to be great. Adequate is not enough. But greatness does not come from standards. Best-selling author Daniel Coyle suggests in his book *The Talent Code: Greatness Isn't Born. It's Grown. Here's How* that greatness comes from deep practice, that is, tens of thousands of hours of practice with master coaching. "But deep practice isn't a piece of cake: it requires energy, passion, and commitment. In a word, it requires motivational fuel" (Coyle, 2009, p. 93). That motivational fuel comes from the inside, not outside, of an individual. Thus, only when children have the autonomy can they be driven enough to become great.

1.11.3 Confident, Curious, and Creative

The world needs creators: creators of more jobs, better products, more sensible policies, more effective business models, and more meaningful human services. Creators are curious people, who keep wondering and imagining. Creators are confident people, who are courageous to think and act outside the box. Creators are, well, creative people, who can come up with novel ideas and solutions. Creators cannot be planned, predetermined, or standardized. They must be allowed the freedom and encouraged to wonder and wander, to explore, and to experiment. They must not be judged against others, a standard norm, or external assessment. They need autonomy.

To enable autonomy and personalized education, new educational institutions in the future should have three features: student voice, student choice, and student support.

1.12 Student Voice: Governance and Environment

In the future, schools should become learning communities in which all members, teachers, students, administrators, and other staff, are all equal members. Students co-own the community. Thus, they should have the same right and opportunity to participate in school governance and constructing the physical, social, and cognitive environment as others. Students should play a substantive role in defining the rules of the community, resource allocation in the community, and more important, deciding educational activities in the community.

1.13 Student Choice: Broad and Flexible Curriculum

In the future, students should have certain degrees of freedom to pursue their own interests. Students should be able to construct a personalized education to enhance their own unique strengths as well. Thus, schools must have a broad range of curriculum offerings to enable students to explore, experience, and experiment with their strengths and passions. More importantly, students should not be forced into one preset uniform curriculum.

1.14 Student Support: Personalization and Mentoring

In the future, the role of the teacher is changed from instruction to mentoring and supporting. Instruction, that is knowledge transmission, can and should be done through technology. Online tutorials, AI tutors, videos, simulations, and other technological tools are more effective for individual students than human teachers. But human teachers are much more effective as mentors and facilitators. Thus, in the future, the role of teachers is to provide sufficient and easily accessible emotional, social, and cognitive support for students to personalize their learning experiences. Mentoring and advising are an essential element of personalized learning to help guide, inspire, and facilitate students' learning.

1.15 Creating Value and Product-Oriented Learning: The New How

In the existing paradigm, the primary purpose of teaching is to impart prescribed knowledge in students. It follows a preparatory mindset. All instruction is about preparing for future tasks or just in case the student may need the knowledge in the future. The learning has little immediate relevance to students' life and world.

In the new paradigm, the pedagogy is to help students learn to create value, to learn for a purpose beyond knowledge acquisition. This new approach is called product-oriented learning (POL) (Zhao, 2012). POL changes the orientation of the learner from the recipient and consumer to the creator and provider. It changes the relationship between the teacher and the learner as well. The teacher no longer serves as the sole source of knowledge or disciplinary authority, but rather as a motivator, a reviewer, a facilitator, and an organizer. The learner becomes the owner of their learning and is responsible for seeking and securing the necessary guidance, knowledge, skills, and support to make high-quality products.

1.15.1 Problems Worth Solving

Machines are designed to solve problems, to perform predefined tasks, and to serve predetermined purposes, but what problems are worth solving, what tasks need to be performed, and what purposes should be served should be and can only be decided by humans. In other words, humans should be able to come up with problems, tasks, and purposes for machines. Human beings should also make the moral and ethical judgment about whether a problem should be solved. POL aims to cultivate students' ability to identify problems worth solving and the moral capacity to judge whether a problem should be solved. Thus, POL starts with asking students to identify, refine, and justify a problem worth solving. It then asks the learner to consider problems as opportunities for actions. It inspires them to create solutions, which then motivates them to acquire the knowledge, skills, and resources necessary for creating the solutions.

1.15.2 Other People's Needs

Being able to create value for others and the world is necessary for human beings to be authentically happy and meaningfully engaged (Seligman, 2002). Product-oriented learning compels the learner to care about others because, in order to make meaningful and useful products and services, the learner must first know what is needed and meaningful to different people in different situations. It helps the learner to develop an empathetic perspective on others and the necessary skills to learn about other people's conditions and needs. An acute sense of other people's needs helps develop alertness to opportunities, which is a common trait of successful entrepreneurs.

1.15.3 Strengths and Weaknesses

We cannot be good at everything. Thus, knowing what one is good at or wants to be good at is essential to be successful. Successful people know their strengths and limitations. They stick to what they are good at and "outsource" their weakness to other able people. Product-oriented learning provides learners with the opportunities to try out their interests and talents so they can decide what to pursue and what they need help with.

1.15.4 Perseverance and Disciplined Creativity

Success in life requires perseverance. Unbounded creativity or a flash moment of enthusiasm does not lead to truly meaningful products or successful enterprises. Great ideas lead to great results only when sustained and disciplined efforts are applied over a long period of time. Product-oriented learning, through multiple drafts and peer reviews, helps the learner to develop resilience and perseverance before failure and learn about the importance of discipline and commitment.

In implementation, POL needs to have the following features: authentic products, sustained and disciplined process, and is strengths-based.

1.16 Authentic Products: Personally Meaningful or Useful for Others

Product-oriented learning is a significant departure from traditional learning. The authenticity of student work is a key indicator of the product-oriented learning experience. Authenticity is defined by the degree to which the final product or service serves a genuine purpose, solves a real problem, meets a genuine need of others, or is personally meaningful. If a product only ends as evidence for measuring a student's mastery of certain content or skills, it is not authentic. Thus, in POL, all work students do should be relevant to solving problems worth solving and serving other people's needs.

1.17 Sustained and Disciplined Process: Multiple Drafts and Review

Only when students are engaged in a sustained and disciplined process of product development and marketing can they develop the skills, spirit, and understanding required for creative entrepreneurs. High-quality products can only come from such a process as well. Thus, POL requires students to go through multiple iterations of review and revision with their work. In POL, students do not turn in their work for grades, but for feedback to improve. POL should establish clear guidelines and processes for reviewing and refining student work.

1.18 Strength-Based: Unique and Local

POL turns a classroom or a school or a project team into a global enterprise. In this enterprise, students play different roles that match their interest and strengths. Unlike traditional collaborative learning or project-based learning, POL ensures that students do not work on the same tasks so that they can apply their unique profile of skills and talents. POL also encourages students to identify and acknowledge their own shortcomings and other people's strengths so they can learn about human interdependence and true collaboration. POL also emphasizes local strengths—strengths of each student, teacher, school, and local community.

1.19 Learning From, With, and For Others Globally: The New Where

In the existing paradigm, learning happens in physically isolated classrooms in a place called the school. Students are grouped according to their biological age and taught by one adult, who is typically employed by the school. Students rarely venture out of this setting or interacting with other students or adults during the school day.

In the new paradigm, learning happens in a globalized setting. The campus is globally connected through technology. Students learn from experts and resources within the school and outside the school globally. They also learn with others from anywhere on the globe. More importantly, they learn for others by providing services, creating products and programs, and offers help to people from around the world. This shift is needed for the following reasons.

1.19.1 Global Perspective

In a globalized world where all aspects of human life are interconnected, successful creative and entrepreneurial citizens need to see their work as part of the global economic and political network. They need to know their work affects and is affected by people in other places. Such a perspective is most effectively developed through engaging in experiences with people from other lands or living in other places.

1.19.2 Global Partners

In a globalized world, innovators and entrepreneurs need friends for fresh ideas, different perspectives, local knowledge, and a variety of resources. A global network of friends and partners is thus a tremendous asset. But friends and partners do not just fall from a tree in one's backyard. They become friends and partners only through interactions on various occasions when mutual interests, respect, and understanding are uncovered and developed. Therefore, expanding the campus, the learning environment, beyond the physical boundaries is key to developing global partners.

1.19.3 Global Competency

A globally minded citizen cannot avoid interacting with people and organizations in other countries. To be effective in international settings requires a level of global competency, which ideally includes fluency in a foreign language and a high level of cultural intelligence. Schools intending to cultivate globally minded and competent citizens must provide the opportunities for students to learn foreign languages and become culturally intelligent.

1.20 Conclusion

The core spirit of the new paradigm of education is not new. The idea that education should be centered on the child—not on externally defined knowledge, skills, or rules—has been around for centuries. Child-centered education has also been practiced for decades in institutions such as Montessori schools, Democratic schools, and Reggio Emilia programs. Project-based learning has also been experimented in many places. But the child-centered and project-based education has not been in the mainstream schools. It has been more of a choice, an alternative for the few fortunate children. It has been considered a necessity.

But in the future, child-centered education has become a necessity for all. The paradigm proposed in this chapter advances child-centered education as a way to unleash human potential to combat the challenges brought about by technology. It adds two new dimensions that enable students to pursue their passion, enhance their strengths for the purpose of serving others and bettering the world, globally. In summary, the future education should be one that is driven by students, facilitated by adults, and take place anywhere on the globe.

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Chapter 2
What Is a Smart Classroom? a Literature Review

Yi Zhang, Xing Li, Lingmin Zhu, Xuemin Dong and Qi Hao

2.1 Introduction

In referring to the "smart classroom", there are other terms often used, such as "intelligent classroom", "future classroom", "technology-enhanced classroom", etc. At present, there is no unified definition of smart education. Most commentaries are mainly concerned with the aspects of technical configuration and function in the smart classroom. In China, the main perspectives are as follows. In the era of information technology, network technology, rich media technology and artificial intelligence, the classroom environment should be a kind of new classroom in which teaching content can be optimized to facilitate the acquisition of learning resources to promote classroom interaction, with situational awareness and environmental management functions—this classroom is called the smart classroom. The smart classroom is also a typical smart learning environment that has evolved from the traditional classroom (Huang, Hu, Yang, & Xiao, 2012).

Globally, this concept involves other perspectives. The "intelligent learning environment" is an environment based on the application of information and communication technology, is learner-centered and has the following characteristics: it can adapt to learners' different learning styles and learning abilities; it can provide support for learners' lifelong learning; and, it provides support for ongoing development (Chin, 1997). There are other definitions:

(1) The Smart Classroom is a fully integrated interactive system that allows users to seamlessly access media from a central point;

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(2) The smart classroom can be classified as a classroom with computers, projectors, multimedia devices (video and DVD), network access, loudspeakers, etc., and capable of adjusting lighting and controlling video streams;
(3) The Smart Classroom is a completely self-service environment that helps teach and learn in which teachers use resources in a simple, easy-to-use manner; and,
(4) The smart classroom allows users to interact with them as naturally as possible (Yao, 2015).

Thus, the smart classroom environment makes use of sensing technology, network technology, rich media technology and artificial intelligence technology as a whole, with pad, electronic schoolbag and other one-on-one mobile devices. It can monitor the learners' learning status in real time and collect the process data of student diversity, and can promote students' personalized learning, self-learning and cooperative learning, that support student 21st century skills (communication, critical thinking, creativity, and collaboration).

2.2 The Origin and Background of Smart Classroom

The origins of the smart classroom can be traced back to a presentation by Ronald Reichenio in 1988, but at that time due to the limitations of the development of science and technology, the ideas of a smart classroom had not been vigorously promoted. Chinese intellectual education in the information environment can be traced back to Qian Xuesen as early as 1997 when he began to advocate "Dacheng smart". He proposed the English name "Science of Smart in Cyberspace", where Cyberspace describes the total network interactive information space. "Dacheng smart" also refers to the network smart formed in the vast information space by Immersion (Zhu, 2016).

With the continuous development of information technology, we can use large-scale computer clusters and cloud computing technology to collect, analyze, model, and forecast large data, so as to maximize the use of resources, and get more advice and information to help people make better decisions. In 2008, IBM Chairman, President and CEO. Mingsheng Peng articulated a vision for a "smart earth: the next generation of leadership agenda" and outlined some strategic research for a Smarter Planet, including the smart medical, the smart grid, the smart traffic and smart education (Palmisano, 2008).

Smart education can be seen as an important concept within the context of "smart earth". More recently, Prof. Zhiting Zhu (2016) outlined a comprehensive exposition of smart education. For Zhu, "The essence of smart education is to build the integration of learning environment through a technology, so that teachers can display efficient instructional methods, so that learners can get a suitable personalized learning services and a good development experience, so that everything is possible

Fig. 2.1 Apple TV

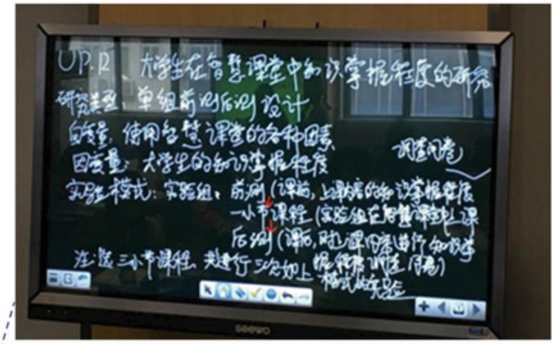
and powerful, so as to cultivate a good value orientation, strong action ability, better thinking quality, and deeper creative potential talents."

2.3 The Basic Equipment and Resources in the Smart Classroom

With the ongoing development of information technology, there will be more and more equipment and resources that can be applied to the smart classroom. Uskov et al. (2016) described software systems in the smart classroom including smart classroom in-class activities recording systems, smart cameraman software systems and systems for seamless collaborative learning (of both local and remote students), and sharing learning content/documents. Klimova and Simonova, (2015) discussed what study materials students prefer in smart learning environments, and showed that a rather large number of respondents welcomed having their study materials in electronic form. Smart devices, particularly smartphones, tablets, pads, etc., are generally understood as those connected to other devices or to networks via various wireless protocols (such as Bluetooth, Wi-Fi, 3G, etc.) and operating interactively, demonstrating a principle of ubiquitous computing (Li, Kong & Chen 2015a, b). Smart devices have been widely exploited for private purposes by learners of all age groups, and are naturally used for learning (Simonova, 2016).

There are some experimental schools with which our team cooperated in carrying out smart education, such as Primary School Affiliated to Central China Normal University, Primary School Primary Affiliated to Huazhong University of Science and Technology, Wuhan Economical & Technological Development Zone Experimental Primary School and Central China Normal University (Figs. 2.1, 2.2, 2.3 and 2.4).

Fig. 2.2 Dual interactive whiteboard



Content translation:
Research on the Knowledge mastery of college students in smart classroom
Study type: single group, pre and post test design
Independent variables: various factors in smart classroom
Dependent variable: knowledge mastery of college students
Research:
Pretest (conduct a pretest regarding knowledge level of learning content; one unit of the course, the target group studying in the smart class
Posttest (conduct a posttest regarding knowledge level of learning content)
Note: choose three units of courses and conduct more than three rounds.

Fig. 2.3 Touchable screen

2.4 Functions of the Smart Classroom and Its Promotion of Learning

Through connecting hardware and software and wireless networks, intelligent linking can be achieved in the smart classroom (Figs. 2.5 and 2.6), which can be a catalyst for subverting traditional classroom teaching habits, and to maximize the use of limited classroom time.

Experts have conducted research on the function of the smart classroom and the promotion to learning, with various points of focus.

Fig. 2.4 iPad

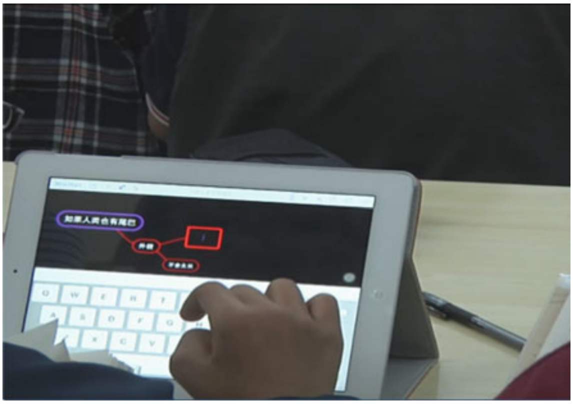


Fig. 2.5 Panorama of the whole classroom at Central China Normal University

Fig. 2.6 Panorama of the whole classroom in K12 education

(1) *Integration of a diversity of technologies and devices*. Li, Kong and Chen (2015a, b) developed a smart classroom by integrating all kinds of interactive technologies, data analysis techniques, and context-aware technologies and devices to support the digital intelligence teaching and learning activities. Avdeeva, Omarova, and Taratuhina (2015) attempted to describe a possibility of an individual approach to learning within a multicultural electronic educational space and proposed a design of a prototype of a "smart educational environment" whose interface and content could be adjusted to a student's cultural-cognitive profile. Bitonto, Pesare, Rossano, and Roselli (2015) presented some solutions of smart learning environment in e-health domain that combines pedagogical approaches of social learning and game-based learning with technological approaches of the social network, combining recommender systems in order to provide engaging learning experiences.

(2) *Facilitated teaching.* The smart classroom has the ability to store, collect, compute, and analyze the massive data of learners to do the optimized pedagogical decisions (Li et al., 2015a, b).

(3) *Enhancing students' meaningful learning in practicing 21st Century Skills*. Students can practice 21st Century Skills regarding communication, information and ICT literacy supported by the intelligent environment. A smart learning environment not only enables learners to access digital resources and interact with learning systems in any place and at any time, but also actively provides the necessary learning guidance, hints, supportive tools or learning suggestions in the right place, right time, and right form (Hwang, 2014).

2.5 The Comparison of Smart Classroom to Traditional Classroom

With the rapid development of information and communication technology in recent years, traditional instruction has already been impacted and changed.

(1) *Transforming the teaching methodologies and learning strategies.* In Smart learning environments, there are some new learning methods, such as cyber synchronous learning, mobile learning, social learning, and ubiquitous learning (Kinshuk, Chen, Cheng, & Chew, 2016). Dabbagh and Kitsantas (2012) proposed that there is an increasing realization that learning can and does happen in any environment, interaction and conversation that the learners engage in.

(2) *Ubiquitous access to ICT improves the convenience and efficiency of learning and teaching.* Compared with traditional learning environments, smart learning environments facilitate just-in-time learning as they can provide various levels of adaptation and precision of diversified learning conditions (including curriculum, course content, strategy, support, etc.) for the learners (Kinshuk et al., 2016). Thus, "advanced data mining techniques can identify relevant patterns, such as where and when learners have difficulties and where their strengths lie"

(Kumar et al., 2014). So, the smart environment facilitates the implementation of teaching with teaching approaches changing to fit the needs of the learners and making it possible for the teachers to monitor an individual learner's learning process.

2.6 Theoretical Foundations

The primary exponents of the theory of constructivism are Piaget and Vygotsky (He, 2006), and after the nineties of the twentieth century reached support for these theories reached its peak worldwide. Swiss psychologist Piaget argued that the cognitive development of children is shaped by both internal factors and external factors formed by joint action, and proposed the concept of cognitive structure, that every child has their own cognitive structure. Children interact or interact with the external environment to expand or change their cognitive structure. Cognitive and social learning constructivist theories give strong support to the design of pedagogical and social activities, respectively (Wang, 2008). Cognitive constructivists acknowledge individual differences and believe individual learners can construct different knowledge even given the same condition.

2.7 Teaching Model in the Smart Classroom

Smart classroom often described as the technology-rich classroom, equipped with wireless communication, personal digital devices, sensors, as well as virtual learning platforms. (Hwang, Chu, Shih, Huang, & Tsai, 2010) The digital facilities enable smart classrooms to be an open learning environment and they provide opportunities for learners to learn in authentic learning context; explore in virtual learning environment as well as provide multichannel for learners to communicate, interact and cooperate (Yau et al., 2003). The environment of the smart classroom can stimulate learners' learning motivation and provide opportunities for learners to engage in individualized and social learning activities. Such an environment can also make visible individual and social learning activities demonstrating their own performance of tasks, routines, or objectives as well as those of the teacher.

Professor Zhang, Bai, and Li (2016) in Central China Normal University has finished some research based on the theory "APT model". As an informative teaching model, APT focuses on the integration of assessment, pedagogy and technology, which will transform the students' learning style into the independent cooperative and exploratory ones. It can also help to build effective classroom teaching activities, to improve students' learning, and to promote teachers' professional development.

This model advocates a scientific and diversified evaluation system. It not only attaches importance to summative evaluation but also pays more attention to process evaluation. Unifying the evaluation before class, in the class and after class, com-

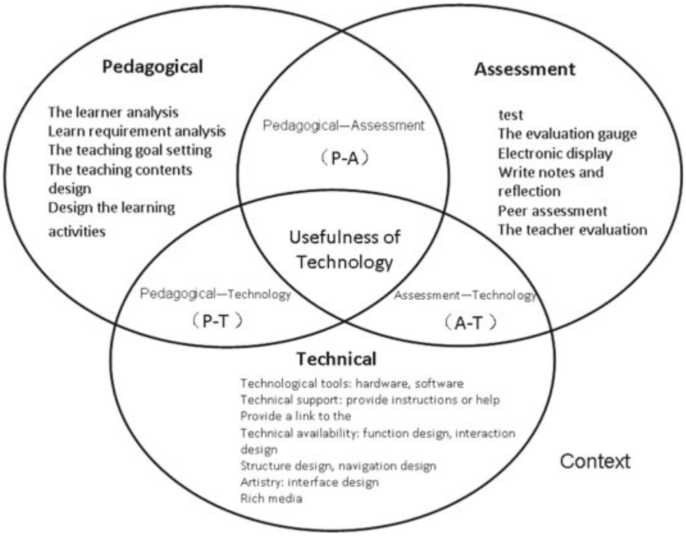


Fig. 2.7 APT teaching model for smart classroom

prehensive use of tests, gauges, teacher observation, learning contracts, real-time evaluation, e-portfolios, peer assessment, and other evaluation methods are all used together. Making full use of a variety of hardware and software tools, such as electronic whiteboards, electronic double boards, iPads, and other hardware, together with discussion forums, concept maps, office tools, email, QQ, and a variety of apps is very important to each teacher. Through the scientific and rational integration of evaluation methods, teaching methods and technical tools, we can transform students' learning as autonomous, cooperative, inquiry and ubiquitous learning methods, and create efficient classroom teaching and cultivate students' knowledge acquisition, sharing, construction and innovation ability, enhancing students' cooperation and innovation ability, active learning ability, information technology ability (Fig. 2.7).

2.8 Teaching activities in the smart classroom

Using a cloud classroom platform as an example, this chapter now describes the case of an elementary school mathematics classroom teaching based on the smart classroom environment of application and implementation and advantage.

Research was carried out to the conclusion that in the smart classroom environment in elementary school mathematics. A key advantage is the smart classroom can assist teachers in aligning characteristics of the students to an innovative design of teaching model, creating a real scene that stimulates student involvement and ability of thinking independently.

Another study focused on an English lesson. Conducted in a networked environment using tablets or electronic books in Hong Kong primary school grade 3 application in the English classroom. The study was concerned with the analysis of student perceptions and identified student learning methods and provided a comprehensive evaluation of electronic textbooks initiated by the Hong Kong education bureau support experiment plan. The English lessons have development of resources and design of teaching materials for different learning phases. In order to ensure that electronic books can be used more effectively in the classroom teaching environment, a primary school is responsible for the implementation of the plan.

Professor Yi Zhang has conducted research both in higher education and K12 education (Zhang, Chen and Li, 2016). There are some experimental schools with which her team cooperates are carrying out smart education and are implementing the smart classroom teaching model. These include the Primary School Affiliated to Huazhong University of Science and Technology, Primary School Affiliated to Central China Normal University, Wuhan Economic and Technological Development Zone Experimental Primary School, and Central China Normal University. In Prof. Yi Zhang's research, several activities were conducted based on the varied APT model at the primary school attached to Huazhong University of Science and Technology. One class was based on mobile learning, using the teaching model based on APT teaching model, while another class was the traditional classroom. For two parallel classes, a total of 100 people participated. From the first grade, the two classes taught by the same teacher began learning mathematics. Through the analysis at the end of the second grade, it was found that there was no significant difference between the two classes. Two classes were randomly assigned to the experimental group and control group based on the teaching environment of the APT teaching model. The students study resulted in significant differences with the traditional multimedia classroom teaching model, showing students' learning interest slightly higher than that of the traditional multimedia classroom, students' experimental cognitive load is higher than the control group, and the appropriate cognitive load was beneficial to the improvement of the students' grades.

In the fifth grade English teaching, the research shows that the electronic teaching materials based on APT model can facilitate the application and implementation of smart classroom instruction, providing a variety of supports for smart classroom learning (Fig. 2.8).

Another case is about the math lesson in the Primary School affiliated to Huazhong University of Science and Technology. The team constructed the mobile learning teaching model based on the APT teaching model, taking the fan-shaped statistical graph of primary school mathematics as an example (Fig. 2.9).

In that research, the following questions were the focus: *How to fully integrate evaluation, teaching, technology, and effective teaching, in the context of information technology environment? Is mobile learning based on APT teaching model superior to traditional classroom teaching?* The findings showed that classrooms based on the APT teaching model of iPad teaching environment, students' learning achievement demonstrated a significant difference to the traditional multimedia classroom. Based on the APT teaching model in the mobile environment, students' academic

Fig. 2.8 Teaching process of the English lesson

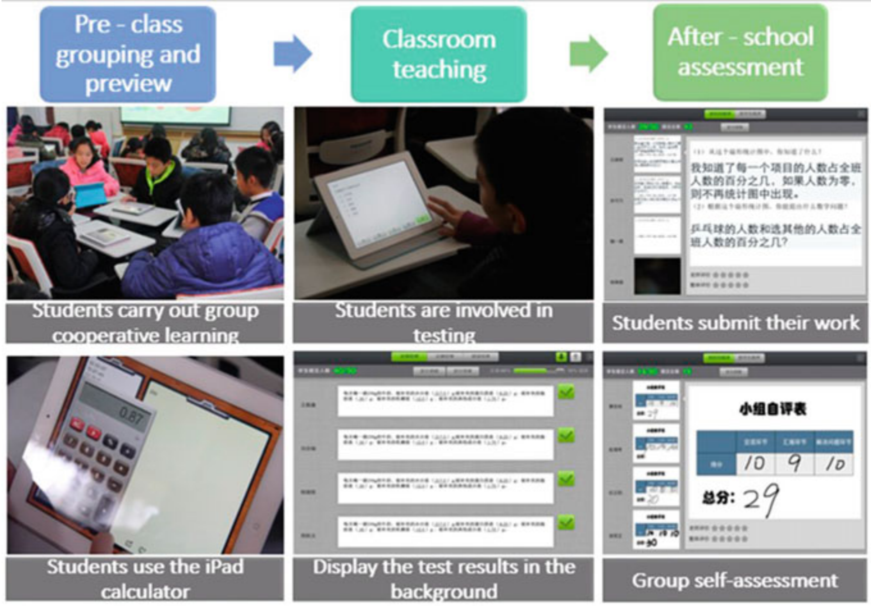


Fig. 2.9 Teaching process of the math lesson

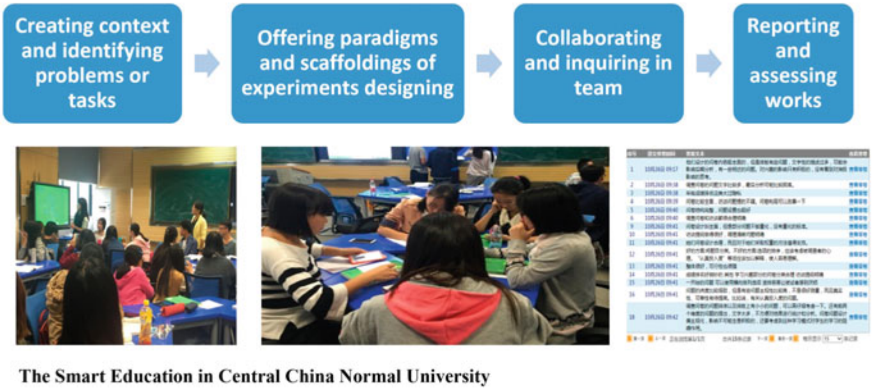


Fig. 2.10 Process of blended learning

achievement is superior to the traditional multimedia environment. APT teaching environment based on the iPad teaching model, students learning interest is slightly higher than the traditional multimedia class. Based on the APT teaching model, the cognitive load of students in mobile environment is higher than that of traditional multimedia environment, but in a certain range, the higher cognitive load is conducive to the improvement of students' academic performance. The progress of the teaching is as follows.

In addition, Prof. Yi Zhang's team applied the APT model in higher education. For example, a case study examined the effect of a scoring rubric on undergraduate students' inquiry skills in a technology-enhanced classroom. Technology included touchable screens for students' collaborative learning, a recording and broadcasting system, wireless network, a dual interactive whiteboard, as well as flexible desks and chairs. The pedagogy in this study included blended learning, problem-based learning, project-based learning, and inquiry-based learning. The formative assessment included teacher, self, and peer assessment (Fig. 2.10).

In this study, two teaching activities were conducted based on the APT model, one with first-year undergraduate students enrolled in Educational Technology Research Methods at Central China Normal University. A class used a scoring rubric, and the other didn't use it before class. For two parallel classes in the present study, a total of 83 people, two classes were taught by the same teacher. The study period is a whole semester. The course is a core component in a degree in Educational Technology. The main objective of the course was to familiarize students with the application of scientific procedures in Educational Technology and cultivate their inquiry skills. In addition, the science course designed in the Primary School affiliated to Central China Normal University, the teacher is better integrated the scientific inquiry into the Electronic schoolbag for science teaching and learning (Fig. 2.11).

Another teacher offered students the scientific background and assigned scientific tasks to the students for them to conduct experiments collaboratively, and then use tablets for searching information on the internet to obtain supportive evidence for the

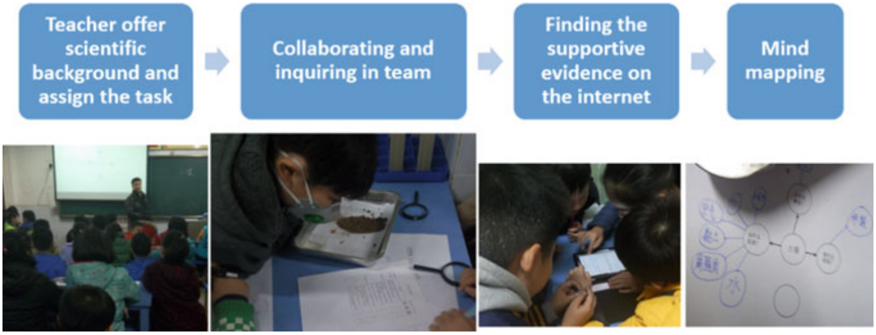


Fig. 2.11 The smart Education in Primary School Affiliated to Central China Normal University

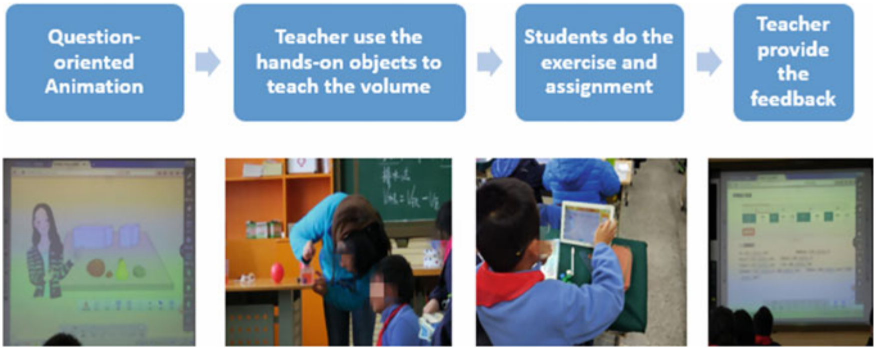


Fig. 2.12 The smart Education in Wuhan Economic & Technological Development Zone Experimental Primary School

results of their experiment. Eventually, they drew mind maps which the teacher then shared with the whole class using the function of a smart classroom, named screen broadcasting to share the mind map.

In addition, a fifth grade math class was asked "To find the volume of irregular objects" in Wuhan Economic and Technological Development Zone Experimental Primary School as an example, where the brand Youxuepai Electronic schoolbag for information technology teaching is used (Fig. 2.12).

At the beginning of the course, the teacher sent daily practice questions to the students' pad through Youxuepai teacher side. Students answered and submitted solutions in their Youxuepai, and the teacher explains the answer according to the feedback from the system. Then, in the lead-in, the Electronic whiteboard shows the flash from the resource library, which demonstrates "how to measure irregular objects, such as potatoes, rubber mud and other deformable objects", stimulating student interest and discussions. The focus of this lesson was how to measure the volume of undeformable objects, such as a glass crystal ball. According to the answers proposed by the students, the teacher made an experiment to demonstrate the use

Fig. 2.13 The smart Education in Wuhan Economic & Technological Development Zone Experimental Primary School

of drainage method to measure the volume of the crystal ball. After the summary, the teacher used the exercises function of Youxuepai again, in order to test whether students master the knowledge and learned how to use it or not.

The above summary outlines the case of the use of the APT model in the smart classroom in Wuhan Economic and Technological Development Zone Experimental Primary School. The creative ability of the students was fully developed while the robot education vigorously introduced. STEAM education involving 3D printing courses was also used for students to develop a wide range of capacities, enriching the meaning of the smart classroom (Fig. 2.13).

2.9 Conclusion

We have introduced some of the concepts of the smart classroom, which include perspectives from China and abroad. We traced the origins of the smart classroom, described the basic equipment and resources in the smart classroom, and summarized three main functions of the smart classroom.

We then considered in more detail of one teaching model of the smart classroom. The informative teaching model, APT, developed by Prof. Yi Zhang, focuses on the integration of assessment, pedagogy, and technology. The model is emphasized from varying degrees that a scientific and diversified evaluation system is important. In the section, we also conclude the theoretical basis which the teaching activities are relying on. Then we specifically introduce the teaching activities based on the APT model.

Some researchers focus on the Framework in the Smart Learning Environment (Serral & Snoeck, 2016). Because challenging, personalized and automated feedback is essential to improve students' learning, Serral and Snoeck plan to study which combinations of feedback content and presentation are recommended in the literature for each specific learning context to increase the use and the impact of feedback. Through the second part of the model and case summary and the above researchers of the future planning, the model of smart classroom will continues to attach importance to the evaluation and feedback of the study and proposes a generic framework combined with the theory of constructivism and other theories to include cooperative learning, problem-based learning with the aim to provide hands-on experience and practice online (Staubitz et al., 2016).

From another perspective, Belskaya et al. (2016) believe that the application of smart technologies in university guidance counseling allows creating a flexible system of student-centered learning. Kaewkamnerdpong (2016) points that Portable EEG devices may become another crucial technology for smart education; portable EEG devices with classification model can not only serve as a tool for indicating the performance of learning/teaching methods but also can be used to develop smart educational materials for better educational outcomes. Elias described mobile-assisted learning result in principles toward building flexibility of instructional design of learning content and operating system (Simonova, 2016). There is also some research that focuses on one fragment of the economic issue, on mapping the costs on the purchase of SMART. Svobodova and Cerna anticipate that the trend will be that there will be an enormous increase in the creation of new teaching materials and that even more new companies dealing with digital media products will enter the business so that, consequently, this kind of products might become less costly technology equipment per one class (Svobodova & Cerna, 2016).

To sum up, new developments in information technology are enabling students to learn at any time in a smart classroom while actively sharing data and engaging in long-distance learning. However, more research is needed on the benefits of tangibles for learning in smart classrooms.

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Chapter 3
Active Learning Classrooms (ALCs)

D. Christopher Brooks

Glossary of Acronyms

ALC	Active Learning Classroom
LCD	Liquid-crystal display
MIT	Massachusetts Institute of Technology
SCALE-UP	Student-Centered Activities for Large Enrollment Undergraduate Programs
TBL	Team-Based Learning
TEAL	Technology Enabled Active Learning
TILE	Transform, Interact, Learn, Engage

3.1 Introduction

Two decades after Robert Beichner, a professor at North Carolina State University, built the first technology-enhanced classroom designed for collaborative, studio-based learning, the experimental formal learning spaces that have come to be known as *active learning classrooms* (ALCs) are on the cusp of becoming a learning space staple at colleges and universities (Beichner, 2014). In fact, active learning classrooms are the overall number one strategic technology for higher education in 2017 and are expected to achieve mainstream adoption (deployed in 61–80% of institutions) in the next 5 years (Grajek, 2017). The spread and popularity of active learning classrooms from the United States to Oceania, Europe, and Asia in recent years have been fueled, in part, by empirical evidence that demonstrates clearly the impact of learning spaces on students' learning outcomes and instructors' teaching practices.

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This review of the literature and presentation of cases of active learning classroom use are the most comprehensive coverage on the subject to date and include only the best pieces of research published around the world on the subject. Specifically, this review includes literature related to assessing the impact of ALCs on student learning outcomes, evaluations of the layouts and furniture of learning spaces, the experiences of students and instructors, and a brief consideration of research on informal learning spaces (nonclassroom spaces).

3.2 Formal Learning Spaces

The revolution in learning spaces higher education has been experiencing for the last two decades is in many ways a response to a paradigm shift in higher education pedagogy from more passive to more active forms of learning. Popularized by Bonwell and Eison (1991), active learning is explicitly student-centered and involves "anything that involves students in doing things and thinking about the things they are doing" (p. 2). Active learning stands in opposition to instructor-centered, passive forms of learning (e.g., listening to lectures) that have dominated the higher education classroom for centuries. Beyond the focus on the student, one of the appeals of active learning is the plurality of activities that can be employed in its service, including the following:

- Class discussion,
- Small group discussion,
- Collaborative group work,
- Team-based learning (TBL),
- Think-pair-share,
- Short, in-class writing exercises,
- Student debate,
- Reactions to media (e.g., video, audio),
- Exercises with manipulables (e.g., Legos, circuits, etc.),
- Gamification of content,
- Poster sessions or gallery walks (i.e., sharing group work with other groups),
- Group quizzes, and
- Learning by teaching.

The other major appeal of active learning is that it has repeatedly been demonstrated to be a superior approach to lecturing in terms of both improving student learning and decreasing failure rates (Hake, 1998; Prince, 2004; Hoellwarth & Moelter, 2011; Freeman et al., 2014).

The major limitation confronting instructors who abandoned the lecture for active learning, however, was that the spaces in which they were teaching their courses were not conducive to activities other than listening to lectures. Traditional classrooms were designed and built with the assumption that lecture would be the primary mode of instruction with a clearly designated front of the classroom denoted by a

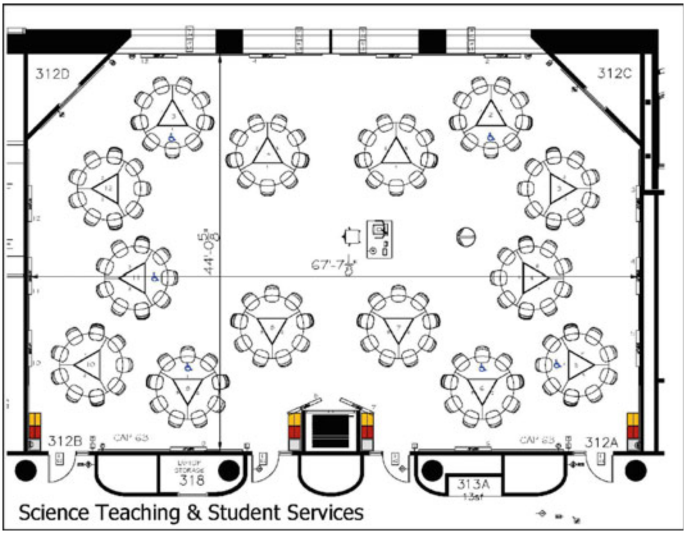

Fig. 3.1 Active learning classroom (ALC) at the University of Minnesota (*Source* www.flexspace.org)

combination of chalk or marker boards, a podium, lectern, or desk, and/or elevated platform or stage. And while it is possible for active learning to occur is such a space, one might expect that formal learning spaces designed with active learning activities in mind would be a more favorable environment for deepening student engagement.

Indeed, these were the expectations that Beichner held when he developed the very first ALCs as part of the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project. The SCALE-UP classrooms were designed to transform the way in which large introductory physics courses were taught by including the round tables for student seating, laptop connectivity, and easy access to lab equipment that would become the basis for future versions of ALCs (Beichner et al., 2007). Building on the basic design of the SCALE-UP classrooms, the Massachusetts Institute of Technology (MIT) (USA) incorporated more technology to allow instructors to incorporate more computer-based simulations and visualizations into their classroom activities (Dori & Belcher, 2005). The University of Minnesota (USA) borrowed heavily from both the SCALE-UP and TEAL models to develop the first technology-enhanced classrooms formally referred to as ALCs (Whiteside, Brooks, & Walker, 2010). The Minnesota model focused heavily on the integration of digital technologies with furniture design and layout to produce several ALCs of various sizes (see Figs. 3.1 and 3.2). Around the same time, the University of Iowa also developed their versions of ALCs known as Transform, Interact, Learn, Engage (TILE) spaces and was the first to develop a faculty development program centered on training faculty how to redesign their courses to fit in these spaces (Van Horne et al., 2014).

Fig. 3.2 Active learning classroom (ALC) at the University of Minnesota (*Source* www.flexspace.org)

In more recent years, colleges and universities all over the United States, Australia, Europe, and, more recently, Asia have either borrowed directly from these ALC pioneers or have been working to develop their own versions of ALCs. Even when there are significant departures from the original models of ALCs, these innovative classrooms "typically feature round or curved tables with moveable seating that allow students to each other and thus support small group work. The tables are often paired with their own whiteboards for brainstorming and diagramming. Many tables are linked to large liquid-crystal displays (LCDs) so students can project their computer screens to the group, and the instructor can choose a table's work to share with the entire class. Wireless Internet plays an important role in retrieving resources and linking to content management systems, and depending upon the size of the room, table microphones can be critical to that every student's voice can be broadcast across the room" (Baepler, Walker, Brooks, Saichaie, & Petersen, 2016, p. 10). Given restrictions that institutions face in terms of costs, infrastructure, and goals, there persists considerable variation in the levels and combinations of low and high technology in ALCs. Regardless of the form, the functional intent of creating a formal learning environment conducive to active learning pedagogies and activities remains largely the same.

3.3 Assessment of Impact

Higher education is bombarded constantly by new applications, new devices, new platforms, and other educational technologies that promise to revolutionize teaching and learning as we know it. Often times, these technologies are purchased, adopted, and/or implemented without any systematic empirical evidence that demonstrates clear benefits either teaching or learning, much less both. Fortunately, ALCs are the one educational technology for which considerable evidence supporting their efficacy for both instructors and students has been produced.

3.3.1 North Carolina State University and MIT

The first evidence that ALCs might have a positive impact on the student experience was produced by a team of researchers from North Carolina State who studied the SCALE-UP classrooms for about 4 years. They found that students who took courses in the experimental classrooms outperformed their peers who took the same course in traditional classrooms and noted that students in the SCALE-UP classrooms reported higher levels of satisfaction and confidence and that underrepresented groups more likely persist in STEM courses (Beichner et al., 1999). In a later study, Beichner and his colleagues analyzed data collected from over 16,000 students across over two-dozen institutions and found that the SCALE-UP classrooms and curriculum have a positive and significant impact on an array of outcomes including attitudes, attendance rates, problem-solving skills, and conceptual understanding (Beichner et al., 2007). Researchers at MIT similarly found that TEAL classrooms and the new curriculum for which they were designed were associated with higher levels of conceptual understanding and lower failure rates than were traditional classrooms and lecture-based approaches (Dori & Belcher, 2005). Despite the groundbreaking efforts of the North Carolina State and MIT researchers to transform formal learning spaces, their early research was limited by a lack of controls in the research design, making it impossible to discern whether or not the observed effects were due to the pedagogy or the learning environment.

3.3.2 University of Minnesota

Researchers at the University of Minnesota used a quasi-experimental design in which the instructor, course, class materials, exams and other assessments, assignments, pedagogical approach, and even the time of day were held constant. Post hoc equivalency tests also established that the students in the courses were similar in every way excepting aptitude. The Minnesota researchers found that students in the ALC reported significantly higher levels of engagement, enrichment, flexibility, and course/room fit than their peers in the traditional classroom (Whiteside et al. 2010). Students in the ALCs were also able to overcome deficiencies in aptitude (as measured by a standardized college entry exam) to earn the same grade as their classmates in the traditional space (Brooks, 2011). In a follow-up study under nearly identical conditions, the Minnesota researchers were able to replicate their original findings, solidifying the empirical evidence about the impact of learning spaces on student experiences and learning outcomes (Cotner, Loper, Walker, & Brooks, 2013). Using data derived from classroom observations conducted during the first round of research, the Minnesota researchers also found that the spaces shaped the way the instructor behaved and taught the course, which, in turn, shaped the observed on-task behavior of his students (Brooks, 2012). In summary, ALCs have an independent and significantly positive effect on both teaching practices and learning outcomes.

Beyond the independent effects of ALCs on student learning outcomes, researchers at the University of Minnesota advanced our understanding of importance of the interaction between space and pedagogy in three important ways. First, they found that when an instructor intentionally transforms her course from one that is primarily delivered via lecture to one in which active learning in an ALC is the dominant modality, student learning gains are significantly larger for learners of all abilities (Brooks & Solheim, 2014). In addition to suggesting that instructors should adjust their pedagogical approach to fit the learning environment in which they are delivering the course, this line of research also suggests that lecturing in an ALC might actually limit student learning.

Second, in another longitudinal, quasi-experimental design, researchers tested for the effects of an instructor transforming a lecture-based course held in a large fixed-seat auditorium into an active learning course held in a much smaller ALC by reducing the face-to-face time by two-thirds (e.g., instead of all students meeting three times per week, students were divided into three groups each of which met only one time per week). They found that students achieved learning outcomes (as measured by a standardized exam) that were "at least as good, and in one comparison significantly better than, those in a traditional classroom" (Baepler, Walker, & Driessen, 2014). Such a finding challenges seriously the traditional notions of the meaning of a "credit hour" and the importance of the amount (as opposed to the quality) of contact hours between an instructor and students.

Third, ALCs fundamentally change the network of social relationships that constitute a "social context" along four dimensions: student–student general relations, student–instructor formal relations, student–instructor informal relations, and student as instructor. Student scores on each of these four dimensions have been found to be significantly larger for students in ALCs than for students in traditional classrooms. Moreover, these different dimensions predict student learning outcomes as measured by grades differently with student as instructor and student–instructor formal relations predicting significantly higher grades, student–student general relations predicting significantly lower grades, and student–instructor informal relations having no effect (Baepler et al., 2016, p. 38–51).

3.3.3 *Emerging Research*

Researchers at several other institutions have been conducting their own research to investigate the impact of ALCs on student learning outcomes. At the University of Minnesota-Rochester, Muthyala and Wei (2013) executed a quasi-experimental project comparing two different types of ALCs and found no significant difference in student learning outcomes, suggesting that a variety of different types of ALCs can produce similar results. Ridenour, Feldman, Teodorescu, Medsker, and Benmouna, (2013) found preliminary evidence that students working in an ALC environment using active learning techniques improve their problem-solving abilities. McArthur (2015) found that the interaction between instructors and the physical space of the learning environment impacts students' behavioral, cognitive, and affective learning outcomes, providing additional evidence that instructors should adapt teaching approaches based on classroom affordances and limitations. In another quasi-experimental project at Bethel University (USA) that compared a low- and high-tech version of an ALC, researchers found no significant differences between the two types of spaces and that student collaboration and collaborative writing surfaces were more important than digital technologies (Soneral & Wyse, 2017).

3.4 Empirical Evaluations

In addition to systematic assessments of the impact of ALCs on student learning outcomes, many researchers have been engaged in the processes of evaluating aspects of the physical learning environments and aspects of the student and faculty classroom experience.

3.4.1 *Physical Learning Environments*

Although student evaluations of the spaces in which they take their courses are no substitute for rigorous empirical research that ties spaces to student learning outcomes, they are important in helping us understand students' environmental, furniture, and layout preferences in new learning environments. Another group of researchers at the University of Minnesota sought to understand the relationship between formal learning environments and students' evaluation of the quality of the environments, perceived learning, and course satisfaction. They found that students' evaluations of the quality of their learning environments (e.g., temperature, air quality, acoustics, lighting, furniture, technology, etc.) were positively associated with students' self-reported experiences (Choi, Guerin, Kim, Brigham, & Bauer, 2013–2014).

Researchers at St. Olaf College (USA) evaluated the furniture layouts of three experimental learning spaces in a new science and math building to understand student and faculty preferences. They found that faculty preferred a furniture layout that maximized flexibility for both active learning and lecture-based pedagogical approaches. Students, on the other hand, had learning preferences that were activity dependent. For lecture-based courses, students preferred rows of tables; for active learning or mixed pedagogy courses, students preferred the same flexible classrooms preferred by instructors (Walczak & Van Wylen, 2013–14).

When Lethbridge College (Canada) expanded its ALC capacity, researchers have students and faculty evaluate new furniture and technologies included in the new designs. Among the key findings related to students include the following:

- Students in different courses require different amounts of workspace;
- Students preferred sitting near one another at round tables to collaborate; and
- Students utilized mobile charging stations when provided.

Faculty reported experiences similar to those of students:

- Instructors did not find ALCs conducive to in-class assessments;
- Instructors needed more technical and pedagogical training to learn how to use the ALC more effectively;
- Instructors found ALCs to be more flexible compared to traditional classrooms; and
- Instructors found ALCs to be more pleasant than traditional classrooms.

Both students and instructors found ALCs

- To be more welcoming than traditional classrooms;
- To be more comfortable than traditional classrooms;
- To be more conducive to group work than traditional spaces; and
- To improvements in student–student interactions (Benoit, 2017, p. 22–23).

The furniture used in ALCs is essential to creating learning spaces conducive to active learning techniques. Indeed, for years students have cited the round tables and movable chairs typically found in ALCs as the most important technology in the rooms (Whiteside et al. 2010). Given the variability in budgets, desired outcomes, and spaces available in which to create ALCs, many institutions have experimented with a range of different furniture options and have shared the results with the larger learning spaces community. At the University of North Carolina, researchers evaluated the use of innovative fixed swivel desks in an experimental classroom (see Figs. 3.3 and 3.4) finding that the furniture and layout promoted student interaction, created clear pathways for instructors to move about the room and have access to students, and promoted easier transitions from one instructional modality to another (e.g., lecture to group work) (Henshaw, Edwards, & Bagley, 2011). Also, at the University of North Carolina, the combination of mobility and surface workspace led both language students and faculty to prefer an experimental tablet chair under quasi-experimental conditions (Henshaw & Reubens, 2013–14). Researchers at Buffalo State, State University of New York (USA) had students evaluate five classroom seating arrangements—modern mobile chairs, tablet armchairs, fixed tiered seating with tablet arms, rectangle tables with standard chairs, and trapezoid tables with

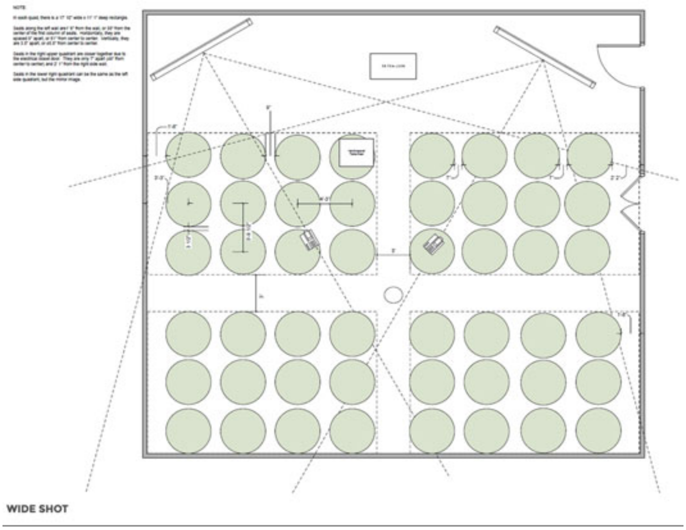

Fig. 3.3 Schemata for Peabody Hall 311, University of North Carolina Chapel Hill (*Source* www.flexspace.org)

Fig. 3.4 Peabody Hall 311, University of North Carolina Chapel Hill (*Source* www.flexspace.org)

chairs on casters—in terms of comfort and space, engagement, and interactivity. They found that students preferred the trapezoid tables and chairs on casters and modern mobile chairs to all other types of arrangements and used that data to inform furniture purchases and room designs for eight new technology-enhanced classrooms (Harvey & Kenyon, 2013).

3.4.2 Student Classroom Experiences

Student perceptions of their experiences are critical components to understanding the impact of ALCs on a host of unobservable and difficult to measure constructs. While the self-reported nature of the data may undermine its empirical reliability, we cannot and should not dismiss students' evaluation of their own experiences as end users of learning environments. Indeed, students can be far more perceptive than we might give them credit. Moreover, these experiences appear to be similar to one another despite considerable variation in geography and culture.

Students at Macquarie University (Australia) thought that courses taught by instructors who had undergone professional development opportunities to learn how to teach in ALCs were associated with higher levels of engagement, learning, and satisfaction (Robertson, 2013). At the same university, researchers found that the design and technology of active learning spaces allowed students to interact with each other and with staff more, made students more comfortable, facilitated problem-solving class styles, and made delivering student presentations considerably less awkward (Bulger, Gudlaugsdottir, Bilgin, & Robertson, 2013). Byers, Imms, and Hartnell-Young (2014) found that students taking courses in "next-generation learning spaces" at Australian schools evaluated them and their ability to engage them in the learning process significantly more positively than traditional classrooms.

Using data collected at several different institutions, researchers at the University of Tehran (Iran) found that learning spaces can and do have a positive and significant impact on students' attitudes toward engaging with one another in group work activities (Beigi & Shirmohammadi, 2012). In a semester length comparative research project, students at the Monterrey Institute of Technology and Higher Education (Mexico) experienced significant shifts in their expectations about class discussion, group work, and other active learning tasks in ALCs. In contrast to the Bethel University case cited above, researchers from Hangzhou Normal University and Southeast University (China) and National Sun Yat-sen University (Taiwan) found that elementary school students experienced greater levels of teacher support, involvement, investigation, cooperation, and task orientation in high-tech classrooms (e.g., Wi-Fi, personal iPads for each student, multiple screens, etc.) versus those with basic multimedia features (e.g., projector, teacher computer) (Yang, Yu, Gong, & Chen, 2017).

In a quasi-experimental design, students at Kennesaw State University (USA) not only perceived differences between innovative and traditional classrooms, preferring the former, but also reported significantly higher levels of learning and enjoyment. The instructors in new spaces, who were rated higher by students in terms of their organization, reported higher levels of satisfaction and received better teaching evaluations from students than did faculty teaching in traditional spaces (Hill & Epps, 2010). Researchers at Purdue University (USA) found that students evaluated the impact of ALCs on adaptability, comfort, ease of use, instructor–student interactions, variety of furniture, and ability to concentrate more favorably than traditional classrooms. Conversely, students thought ALCs had too much furniture, could become too disorganized quickly, were too cozy (encouraging naps), and did not have enough work surface space. Most importantly, the Purdue researchers concluded explicitly what we have suggested above the student perceptions need to be included when planning learning spaces (Adedokun, Parker, Henke, & Burgess, 2017).

3.4.3 Faculty Classroom Experiences

Although most studies have focused primarily on students and their experiences, researchers are increasingly paying more attention to the faculty experience. And while faculties represent the supply-side to the students' demand-side of learning in the classroom, faculties are also end users when it comes to learning spaces. Accounting for their experiences and perceptions is also critical when evaluating innovations in formal learning environments. Indeed, Rook, Choi, and McDonald (2015) argue fiercely for the inclusion of faculty into the learning space design process given their expertise on teaching and learning, subjects about which architects may know very little.

Faculty experiences are particularly important not only because they bring an approach to teaching to learning spaces and are, in turn, shaped by those spaces, but also because they impact the students' experiences. For example, researchers compared data from courses held in Bahauddin Zakariya University Multan (Pakistan) in technology-enhanced classrooms and courses from its affiliates that were more traditional facilities. They found that instructors teaching in classrooms more conducive to active learning (with educational technology accouterments) took a more "communicative approach" to their peers (Ahmad & Rao, 2012). Oregon State University (USA) researchers found that experience matters when it comes to quality instructor–student relationships in ALCs. Specifically, more experienced teaching assistants were efficient instructors when dealing with students in ALCs (e.g., least amount of time per student; most consistent amount of time with each student) and the converse is true with less experienced instructors (DeBeck & Demaree, 2012).

Canadian researchers employed a quasi-experimental design at a 2-year public institution to test for the impact of the intersection of different pedagogies and spaces. Their efforts produced results that resemble closely the Brooks and Solheim (2014) results discussed earlier:

- Student-centered pedagogies in student-centered spaces is the most effective combination;
- Instructor-centered pedagogies in a student-centered space is not only ineffective, but may be detrimental to the teaching and learning experience;
- Learning gains are correlated positively with self-reported student-centered pedagogies; and
- Student-centered classrooms elicit more student-centered pedagogies from some instructors (Lasry, Charles, & Whittaker, 2014).

South of the Canadian border, researchers from the University of Iowa (USA) found that

- ALC environments served as catalysts to inspire instructors to redesign their courses and classroom activities to take advantage of the affordances of the technology and spaces offered;
- A flipped classroom model in which students complete didactic, lecture-based materials prior to class and engaging in active learning in class works best; and
- When faculty scaffold, rather than micromanage, learning activities, students perform well (Van Horne et al., 2014).

In a quasi-experimental study, researchers at Seattle Pacific University (USA) explored how faculty perceptions of student engagement are shaped by the intersection of pedagogical approaches and the spaces in which they are teaching. Specifically, they found that faculty found students to be more engaged in ALCs than traditional classrooms and that instructors with a stronger disposition to active learning perceive students to be more engaged in ALCs than in traditional classrooms, but the difference between less and more constructivist pedagogies persisted significantly only in ALCs (Sawers, Wicks, Mvududu, Seeley, & Copeland, 2016).

Teaching in ALCs appears to have a transformative effect on many instructors. For example, faculty who taught in ALCs at the University of Hong Kong (China) also experienced fundamental shifts in the manner in which they taught their courses and that these experiences were carried forward into subsequent courses (Salter, Thomson, Fox, & Lam, 2013). Carr and Fraser (2014) and Van Horne et al., (2014) advocate strongly for more faculty development programs centered on helping instructors learn how to teach in ALCs. Alleman, Holly, and Costello (2013) chronicle one such effort in which they discuss in detail how they designed a faculty development to overcome barriers to technology integration and provide support faculty at their American university. They found that among faculty who embraced the transition to adopting more technology, they tend to (1) use and think about it in more deliberate terms and (2) experiment with new collaborative tools more frequently. Conversely, researchers at Indiana University (USA) gathered evidence that suggest that ALCs do not exert enough power over faculty to fundamentally change their pedagogical approaches. That is, faculties who tend to lecture continue lecturing in ALCs; faculty who are more prone to constructivist pedagogies and active learning embrace the affordances of ALCs to innovate (Morrone, Ouimet, Siering, & Arthur, 2014).

In 2016, Baepler et al. published *A Guide to Teaching in the Active Learning Classroom: History, Research, and Practice* to facilitate that process. The structure of the book follows closely its subtitle, providing

- A history of the development of ALCs and a literature review of relevant research.
- Several practical chapters on
  - Common teaching challenges,
  - Assignments and activities,
  - Managing student groups,
  - Assessment and feedback,

  – Supporting all students, and
  – Supporting faculty.

- A brief how-to guide for designing learning spaces research (Baepler et al., 2016).

The authors designed the book to provide a troika of information types for the reader:

- Evidence of impact.
- Tips and suggestions grounded in research and experience.
- Help with designing research and evaluation projects.

This book is proving to be a valuable resource for those needing practical and hands-on advice for instructors and faculty developer all over the world.

3.5 Conclusion

The evidence is mounting that ALCs have an impact on student learning experiences and faculty teaching practices. Beyond engaging students more in the learning process and fomenting changes in pedagogical approaches, ALCs have been demonstrated to have a positive and significant impact on student learning outcomes as measured by grades and standardized exams. And while ALCs are being heralded as the most strategic technology in 2017 and are expected to become mainstream within the next 5 years, we still have a lot to learn about them. We would all benefit greatly from continued research and evaluation of these innovative classrooms that we have come to know as active learning classrooms or ALCs.

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Chapter 4
Intelligent Learning Environments: Design, Usage and Analytics for Future Schools

Manolis Mavrikis and Wayne Holmes

4.1 Introduction

With the recognition of education as a pillar for a sustainable future (e.g. United Nations, 2015), educators, policy makers and parents are in search of ways to provide cost-effective and at the same time quality teaching and learning opportunities for students. Technology has been promoted as a solution to this challenge for decades. The emergence of artificial intelligence techniques and advancements in the analysis and visualisation of data are transforming learning technologies and introducing a genre of tools that can support students directly and provide information about their learning to teachers and parents (Holmes, Bialik, & Fadel, 2019).

There are several terms and ways to refer to this technology. This chapter refers to Intelligent Learning Environments (ILE) as a broad category of digital educational interactive applications equipped with features that enable the provision of personalised, adaptive support to students (either by means of task selection or adaptation, or dynamic assistance while students are undertaking a task). This expands on older definitions that centre on student assistance during problem-solving (Dillenbourg, Hilario, Mendelsohn, Schneider, & Borcic, 1994) or student-driven learning (Brusilovsky, 2004). Depending on the subject matter that these systems are designed to target, and the type of learning that they are promoting, the system–student interaction is characterised differently. For example, the system-student interaction may be referred to as *tutoring* (hence Intelligent Tutoring Systems), when the interaction is designed around the steps that students take when solving a problem (VanLehn, 2011). At other times, it may be referred to more generally as *intelligent*

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support when the interaction is more open-ended or exploratory (Gutierrez-Santos, Mavrikis, Geraniou, & Poulovassilis, 2012).

The next section provides a brief historical account of the field and presents design architectures and implementation approaches, which are further explained by means of an example. The chapter then discusses common usage models in the classroom, particularly highlighting the approach known as blended learning. Before concluding, we review evaluation studies and meta-analyses in relation to the efficacy of ILE, raising some concerns around how they should be interpreted.

4.2 Intelligent Learning Environments

4.2.1 A Brief Background

The idea of technology for instruction has fascinated researchers and educators from the beginning of twentieth century based on the educational psychology theories first of Thorndike and later of Skinner (Januszewski & Molenda, 2007). This led to the so-called computer-assisted instruction that flourished in the 1960s and 70s (Shute & Psotka, 1994; Forbus & Feltovich 1989) with perhaps the most prominent example being the PLATO system (Chambers & Sprecher, 1983). Fast forward 35 years and the advances in computer science and artificial intelligence techniques have made their way in various forms of educational technology through a combination of entrepreneurial efforts and research and development particularly in the fields of Intelligent Tutoring Systems (ITS) and Artificial Intelligence in Education (AIED), which, as mentioned in the introduction, together we summarise as Intelligent Learning Environments.

Although a comprehensive review of ITS/AIED is outside the scope of this chapter, a brief discussion of terminology will be helpful. It is commonly accepted that, among other components (such as the actual learning environment or *user interface*), an intelligent system usually involves three 'models' (i.e. computational representations of something in the real world) (Fig. 4.1). The *learner* model represents information about the students (for example, about student preferences, achievements, challenges, and emotional states both for all the students who have used the system so far and for the individual student using the system right now). The *pedagogy* model represents strategies for teaching and learning (for example, about collaborative learning, feedback and approaches to assessment). And the *domain* model represents knowledge about the subject that the system is aiming to help the student learn (for example, about mathematical procedures, the laws of physics). The system's algorithms draw on these three models to adapt the learning content to the individual student. Different systems put different emphases on these models, and sometimes one or other might not be implemented at all. For more details, the reader is referred to Freedman (2000), Nkambou et al. (2010), and Woolf (2008).

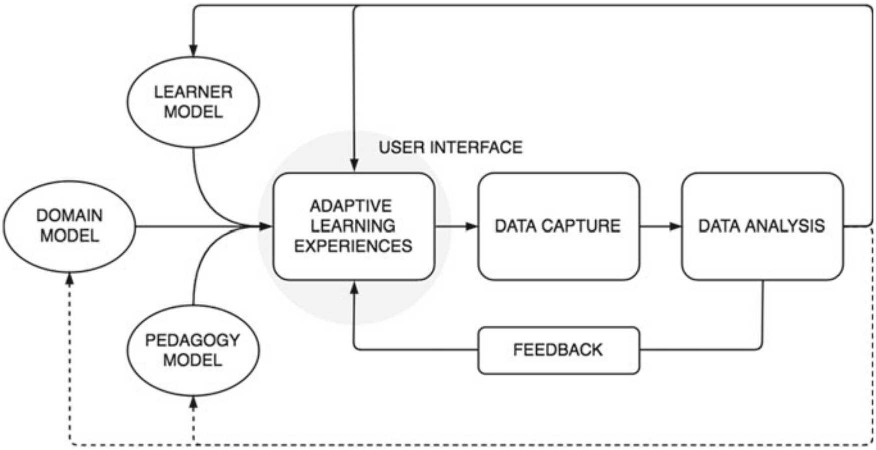

Fig. 4.1 Common parts of an Intelligent Learning Environment (adapted from previous version in Luckin et al., 2016)

4.2.2 Approaches to Designing Intelligent Learning Environments

There are various ways to implement an intelligent environment. The two most common are driven by data or based on knowledge engineering. These are not mutually exclusive and can (and probably should) also be combined. In data-driven methods, techniques such as machine learning are used to help the system 'learn' from past behaviour, e.g. in order to predict the score of a student based on past data that can help decide which task to provide next (e.g. by giving one of appropriate difficulty). For detailed reviews of recommender systems to support learning, the reader is referred to a recent review of the field (Drachsler, Verbert, Santos, & Manouselis 2015).

In knowledge engineering methods, a detailed analysis of the task is required, combined with an understanding of student common misconceptions, difficulties on the particular task, etc., e.g. in order to design the hints and other feedback messages. This often requires involving experts, teachers or other domain experts in what is commonly referred to as knowledge elicitation. There are several approaches to knowledge elicitation that can be combined with the general design approaches in the field recognising the need for iterative, agile processes (e.g. Good & Robertson, 2006; Sharples, Jeffery, du Boulay, Teather, & Teather 1999; Conlon & Pain, 1996) and iterative theory development that explains the phenomena of interest (DiSessa & Cobb, 2004).

One methodological device particularly suitable in complex domains where the introduction of technology has a particularly transformative role is the so-called Wizard of Oz (WoZ) methodology common in the field of Human Computer Interaction, particularly for the design of Intelligent Systems. The WoZ methodology involves design experiments in which the system's 'intelligence' is emulated usually by a hidden human operator who supports a student remotely (see examples and related references in Mavrikis and Gutierrez-Santos, 2010; Eynon, Davies, & Holmes, 2012; Mavrikis, Grawemeyer, Hansen, & Gutierrez-Santos, 2014). In particular, Mavrikis and Gutierrez-Santos (2010) describe the Iterative Communication Capacity Tapering (ICCT) methodology. In brief, ICCT recognises that in-depth understanding of user behaviour requires observing and analysing situations in their actual context. On the one hand, the communication bandwidth is gradually reduced: starting with a teacher interacting normally face to face with students, the situation evolves to remote interaction where teacher and student are physically separated. On the other hand, the capacity for improvisation is also reduced: at first the teacher can support the student with any words or actions at will, but gradually their options are limited until there is a script that describes when support is provided.

Regardless of the exact knowledge elicitation method, a principled approach to design is needed. This is because the leap from some understanding of what kind of support students need to the actual implementation of that support (and its subsequent maintenance and/or modification) is not an easy one. There are several tools, approaches and methodologies that are emerging. Gutierrez-Santos, Mavrikis, and Magoulas (2012) present a divide-and-conquer strategy that separates the difficult tasks of development and evaluation of intelligent support in ELEs in four layers which they refer to as FRAME (Feedback–Reasoning–Analysis–Model/Events). In short, the strategy considers first three parts, each one focusing on the most important questions related to support at any given moment: (i) what is the situation now? (ii) which aspect needs support? and (iii) how should the support be presented for maximum efficacy? The answers to these questions determine what kind of information should be provided, i.e. what kind of events should be monitored and what representations in the model should be provided. This can be presented diagrammatically as in Fig. 4.2 and has the advantage of easier testing and validation and better communication and management of interdisciplinary teams (ibid.).

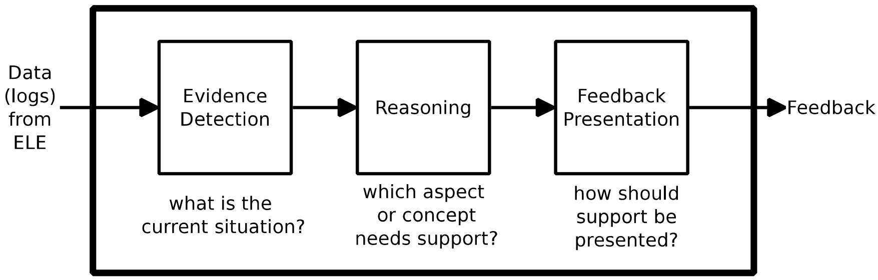

Fig. 4.2 Conceptual data flow of support for exploratory learning (from Gutierrez-Santos et al., 2012)

4.2.3 An Example—The ITalk2learn Platform

As we do not have sufficient space to review the field (books and recent reviews provide the necessary detail, e.g. du Boulay, 2016; Baker, 2016; Woolf 2008), in this chapter we provide one example of a comprehensive platform that contains several characteristics of other ILE and also uses speech-recognition technology.

Our example is iTalk2Learn, an EU-funded project[1] which developed a proof-of-concept adaptive digital learning platform for primary mathematics that:

- combined structured and exploratory activities to improve learners' conceptual knowledge as well as their procedural knowledge (Rummel et al., 2016)
- allows interaction with the tutoring system via the direct manipulation of virtual manipulatives (Hansen, Mavrikis, & Geraniou, 2016) and via speech (Mavrikis et al. 2014; Janning, Schatten, & Schmidt-Thieme, 2016), and
- includes intelligent and individualized interventions based on the student's past and current behaviour (Mazziotti et al., 2015; Grawemeyer et al., 2017).

We now describe these parts in more detail starting with Fractions Lab.

4.2.4 Fractions Lab

Fractions Lab is a central component of the iTalk2Learn platform. It is an exploratory learning environment aiming to foster conceptual understanding of fractions (i.e. their underlying principles and structure). Fractions Lab encourages student-directed activity with open-ended tasks designed to support students' conceptual development. Examples of the tasks include (i) constructing three fractions equivalent to 3/5, (ii) finding the odd fraction out, (iii) making a fraction equivalent to ¾ that has a denominator of 12 and (iv) explaining whether another student is correct or incorrect.

A detailed description of the design decisions behind Fractions Lab can be found in Hansen et al. (2016). Here it suffices to say that various tools enable a student to change the numerator and denominator, partition the models, or copy a fraction. The addition, subtraction and comparison tools (at the top of the screen in Fig. 4.3) allow students to check their hypotheses.

[1]This research received funding from the European Union Seventh Framework Programme (FP7/2007–2013) under Grant Agreement No. 318051—iTalk2Learn project. Thanks to all our iTalk2Learn colleagues for their support and ideas. For more details on the project see http://www.italk2learn.eu.

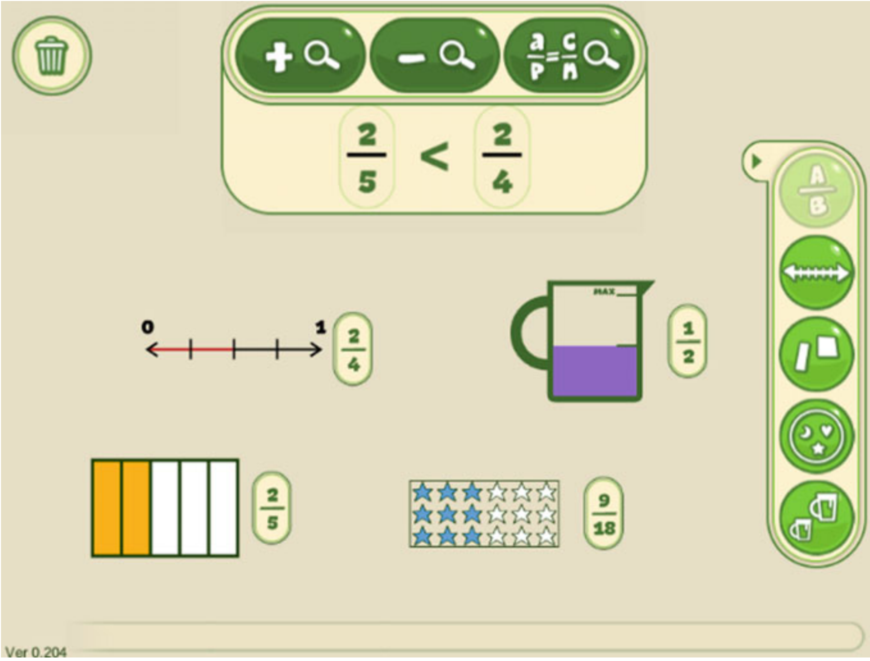

Fig. 4.3 Screenshot of Fractions Lab with various representations

4.2.5 Feedback

As students are undertaking tasks in Fractions Lab, a component of the platform provides *task-dependent support*, i.e. support that aims to enhance the students' learning of fractions by responding flexibly to their ever-changing needs in the particular task they are undertaking (Holmes, Mavrikis, Hansen, & Grawemeyer, 2015) (Fig. 4.4). Drawing on the literature and the outcomes of our Wizard of Oz studies, the feedback framework rules have been operationalised according to two dimensions: *the purpose of the feedback*, depending on the task-specific needs of the student and reflecting the recursive and iterative problem-solving processes involved in exploratory tasks, and *the level of feedback*, depending on the cognitive needs of the student providing either (i) open questions to encourage students to think about and verbalise possible solutions (Socratic feedback), (ii) supportive information mostly to remind students of the system's affordances (guidance) (iii) suggestions on next steps either at conceptual level (didactic) or (iv) at procedural level ensuring that wherever possible the student is not left floundering (ibid.).

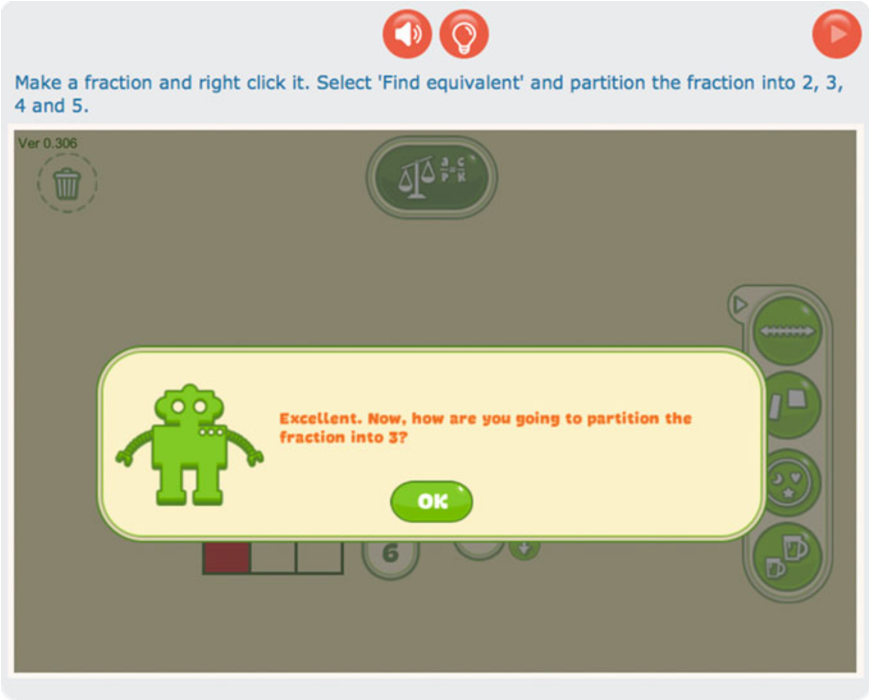

Fig. 4.4 A feedback message on Fractions Lab

4.2.6 Speech-Based Affect-Aware Support

While students are interacting with iTalk2Learn, they are asked to talk aloud about their reasoning process. This is used by the platform to detect and analyse the student's speech in near real time. The analysis of the speech and the student's interaction with the exploratory learning environment are used to detect their affective (emotional) states. In this way, the platform provides adaptive support based on students' affective states. In particular, relying on a naïve Bayes classifier and keywords, the system infers affective states and from prosodic features (such as 'um's and pauses), a module called 'perceived task difficulty classifier' (PTDC) predicts the level of challenge for the current student (Janning et al., 2016). Lastly, the student's interaction with the platform is used to add evidence towards an affective state, e.g. if the student has viewed but not followed the most recent feedback, it infers that the student is confused (for details see Grawemeyer et al., 2017).

4.2.7 Task Sequencing

In addition, the system uses past data to infer the difficulty of a subsequent task and, thanks to a detailed intervention model (Mazziotti et al., 2015), sequences tasks (from Fractions Lab and other tools) that are most likely to help the students are given tasks that help develop both procedural and conceptual understanding of fractions (Schatten, Janning, & Schmidt-Thieme, 2015).

4.2.8 iTalk2learn Architecture and Components

The iTalk2learn platform was designed around the key ILE components described earlier, while using a design approach that separated concerns to different layers of model/events, analysis, reasoning and feedback. Figure 4.5 presents this diagrammatically and more detail is provided in Grawemeyer et al. (2017). In brief, it is worth drawing attention to the student model that includes both cognitive and non-cognitive aspects based on the outcomes of an analysis layer that takes into account

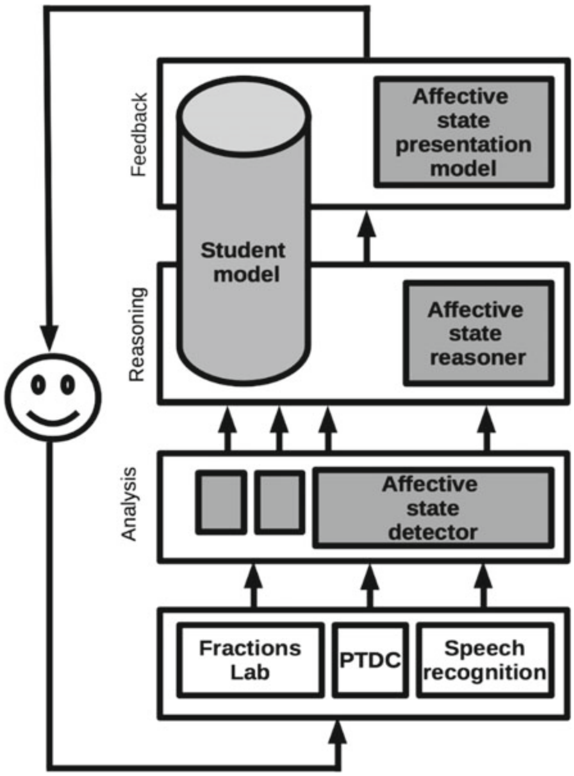

Fig. 4.5 The iTalk2learn architecture and conceptual design

both the interaction with Fractions Lab and the affective states detected. Building on the analysis layer, the reasoning layer decides *what* feedback should be provided, by using an affective state reasoner implemented as a Bayesian network which draws on information from the learner model. In its turn, the *feedback* layer decides what's the best feedback to provide to maintain or improve the students' affective states.

4.2.9 Usage Strategies and the Role of Learning Analytics

It is important to consider carefully the way ILE are integrated in everyday learning. The promise that they will meet each child's individual needs relies on them being used in appropriate ways and at appropriate times in combination with other learning resources. While the arguments from the research community explicitly or implicitly advocate the role of ILE as replicating high-quality one-to-one tuition (c.f. VanLehn, 2011), this should not be taken to imply that they are supposed to be (or that it is possible for them to be) used in a way that replaces teachers. On the contrary, a more realistic vision seems to be emerging that appreciates that ILE can and should be used in ways that are complimentary to human-led teaching (Baker, 2016; Luckin et al., 2016; Holmes, Anastopoulou, Schaumburg, & Mavrikis, 2018).

4.2.10 Blended Learning

One way in which this vision is being realised is through what are known as 'blended' models of instruction, i.e. models that reconcile a component of online- or digital-based learning with face-to-face supervision and instruction at school or other learning settings (cf., Buckingham, 2013; Cheung & Slavin, 2011). Horn & Staker (2011) categorised the majority of blended learning programmes emerging across the K–12 sector, while Christensen, Horn, and Staker (2013) revised that taxonomy and analysed the various models for their potentially disruptive role in classrooms. Perhaps for ILE the most relevant of these models are the variations of a 'rotation' model, in which students rotate on a fixed schedule between computer-based activities and face-to-face teaching and student group work (group work can give time for the teacher to oversee the computer-based work). This approach is often the de facto case in many schools due to the low number of available computers.

In a similar way to how students might work one-to-one with a human classroom assistant (if one is available), students might also work with a technological classroom assistant, such as an ILE, for either extra practice, or to deepen background knowledge or for more challenging material as extension tasks. Students can also be asked to access such tools from home in what's known as a 'flipped classroom'. This is another variant of a rotation model, in that it involves rotation between the home, for access to online content and instruction, and the school, for face-to-face teacher-guided practice (see Christensen et al., 2013 and for commercial examples adopting such strategies 'Cognitive Tutor' (Pane, Griffin, McCaffrey, & Karam, 2014) and (Mavrikis et al., to appear). In most 'flipped classrooms', students are asked to watch a particular video at home before they engage in a related classroom activity (Lowell Bishop & Sams, 2012). With ILE, students might be asked to use the ILE at home, as homework or preparation, and then to resolve queries with their face-to-face teachers or classroom assistants, or to apply what they have learned, at school. This approach also enables teachers opportunities to deliver a plenary based on what the students have found challenging by relying on their usage data, as described below.

4.2.11 Learning Analytics

A great benefit of using ILE for learning in this way is that the data generated by the environment can be used to augment human-led instruction, and to encourage parental engagement. This is possible through the emergence of so-called Learning Analytics or Educational Data Mining tools (du Boulay, Poulovassilis, Holmes, & Mavrikis, 2018) that are devising multiple computational techniques to gather, analyse and visualise data about learners and processes of learning. Visualisation, often in the form of 'dashboards', and other tools can help teachers integrate ILE systems in the classroom, increase their awareness and ultimately free up time to provide nuanced support to students, beyond what is possible through the system (Mavrikis, Gutierrez-Santos, & Poulovassilis, 2016).

There are several examples of such tools emerging that mostly visualise student performance data (c.f. Sclater, 2017). As an example, Fig. 4.6 is from the EU-funded Mathematical Creativity Squared (MC2) project that designed tools to assist teachers to reflect on the use of interactive mathematical e-books. A key characteristic of these e-books is the inclusion of dynamic, interactive widgets that target creative mathematical thinking and problem-solving rather than procedural knowledge (Kynigos, 2015). Teachers use these e-books in several ways including in blended and flipped learning approaches, as discussed above. The system collects and visualises students' interaction data, on which a teacher can reflect before their next teaching. The top part of the figure shows the focus of the dashboard's information, with the structure of the e-book (consisting of three pages each one of which contains two widgets). The nodes in the tree are selectable. The teacher can use them to navigate to different levels of the e-book and display the respective visualisations per page (e.g. in this case, simple descriptive statistics on the users of the book).

While this type of data has been used in the field for many years, the power of intelligent systems lies in how the data that is generated by the system is *analysed* and in the provision of *actionable information*. As an example, the bottom part of the figure visualises data generated by the system in relation to the students' goal achievements (see also related research presented in Mavrikis et al., 2016). The *Users* tab shows data from a live classroom or retrospective snapshots. Each student is represented by a coloured circle (which the teacher can position to reflect the students' position in the classroom; in this case, in groups of three), which contains a

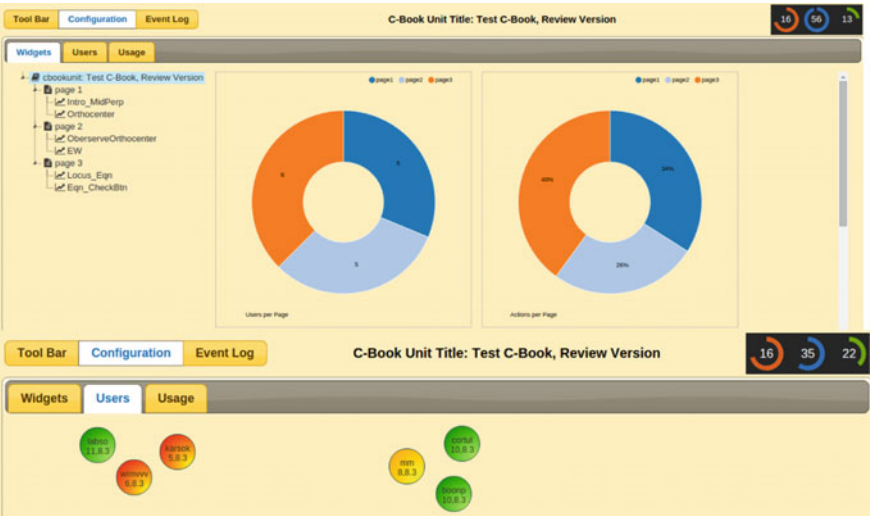

Fig. 4.6 Usage data visualisations from the Intelligent Learning Environment MC2 (from Mavrikis & Karkalas, 2017)

number representing the system's interpretation of the student's intensity of activity. The colour of the circle provides a summary indicator (green represents *high activity*, yellow *low activity*, red *very low activity* or *needing help*). The first number in each circle shows how many actions have been performed by the user so far, while the second shows the average for all the students. This allows teachers to take actions, such as setting additional activities to students, suggesting that they help each other, or prioritising which student to help first.

Other emerging examples of visualisations or related Learning Analytics include post analysis of the system's data logs for helping teachers understand students' behaviour in adaptive tutorials (Ben-Naim, Marcus, & Bain, 2008), providing awareness information to teachers so as to support their role as moderators of multiple e-discussions (Wichmann, Giemza, Hoppe, & Krauß, 2009), analysis of computer-supported collaborative interactions to help the teacher (Voyiatzaki, Polyzos, & Avouris, 2008), and a suite of learning analytics tools for exploratory environments (Mavrikis et al., 2016) that includes a grouping tool that supports teachers in managing group discussion activities based on student algebra constructions in an exploratory environment (Gutierrez-Santos, Mavrikis, Geraniou, & Poulovassilis, 2017). These examples are all a response to the appreciation that Intelligent Learning Environments are limited in supporting students directly and that there is a need to address the requirements of the teachers in supporting blended learning in ways that can begin to simplify its delivery but also open up opportunities for teacher-interpreted evidence-based instruction and decision-making. Holstein et al. (2017) provide an insight into useful analytics based on teacher interviews and implications for future dashboard designs that can effectively support teachers in classroom settings.

4.2.12 Efficacy

The field's long history is full of research findings that provide piecemeal evidence of the efficacy of a specific ILE (the proceedings of the Intelligent Tutoring Systems and Artificial Intelligence and Education conferences attest to that). However, one should bear in mind that educational technology is a field where mostly positive results are reported and some challenge the impact evaluations (c.f. Selwyn, 2011, p. 84).

However, a few large studies and meta-analysis are beginning to emerge. Examples of large-scale studies include, in the US, a randomised controlled field survey by the RAND Corporation, which revealed a statistically significant impact of eight percentile points for students who used Carnegie Learning's Cognitive Tutor Algebra I material (Pane, Griffin, McCaffrey, & Karam, 2013). A recent large study from SRI Education showed the potential positive impact of the homework intervention ASSISTments, developed by Worcester Polytechnic Institute, on students' mathematics achievement (Roschelle, Feng, Murphy, & Mason, 2016). However, although these studies are both worthy of serious consideration, the rigour of their methodologies has been questioned (Holmes et al., 2018).

In recent years, several meta-analyses have been produced that are beginning to help us develop an understanding of the potential of Intelligent Learning Environments. Most are in the area of Intelligent Tutoring Systems and compare with one-to-one or large classroom instruction (a useful summary is provided by du Boulay, 2017). One of the largest meta-analyses is from Ma et al. (2014). It focuses on comparisons between intelligent systems and one-to-one human tutoring and large group human instruction, providing evidence that, under the right conditions and across several different school subjects, ITS can indeed 'successfully complement and substitute for other instructional modes' in a variety of models and roles of the ITS (ibid). Earlier, a meta-analysis of 26 studies on the effect of intelligent tutoring systems in K–12 mathematics education between 1997 and 2010, reported that ITS are at least *not harmful* and might be beneficial in terms of student achievement (Steenbergen-Hu & Cooper, 2014). They also draw attention to the novelty effect (ibid., 2014, p. 984) and their finding that interventions of a shorter length than a year were generally more successful than more lengthy ones.

Although some raise concerns about the narrowness of what is being measured and long-term efficacy and impact, these are just two examples from large studies that provide promising results. One common criticism, especially in mathematics education and for systems that promote mostly procedural learning is that mathematics educators do not locate the essence of mathematical thinking in the procedural tasks that are currently typically presented in these systems. This argument, however, may be missing the alternative point that these systems should not be necessarily promoted as replacement of expert teaching but, as discussed earlier, in blended learning models as ‘assistants’ (du Boulay, 2017) or as providing additional complementary learning opportunities or practice opportunities. The argument should also consider the alternatives. While it is easy sometimes to argue against technology, citing the lack of evidence on learning gains, we have to consider the challenges of human tutoring particularly in a world that recognises the scarcity of human teaching resources (e.g. UNESCO, forecasts a shortage of 25 million primary school teachers by 2030[2]). Even assuming availability of teachers, there are also some that challenge common assumptions around the quality of much human one-to-one tutoring (VanLehn, 2011).

4.3 Conclusion

This chapter reviewed the area of Intelligent Learning Environments by providing a brief historical account, key approaches to developing and designing such environments as well as integrating them in the classroom and using the data they generate to drive decisions. We have also outlined evidence emerging in the field from small and large-scale evaluations and made a case against both dismissal and uncritical acceptance of such systems.

Although we must be cautious about how we interpret the results from published efficacy studies, we must also appreciate the difficulty of conducting evaluations in such complex sociotechnical settings. One should, therefore, relate any findings to student goals and desired learning outcomes (c.f. Kirkwood & Price, 2014). A particular concern is that of generalisability of the findings, and more importantly, any issues with applying a system in a different context than the one it was designed for and evaluated. In particular, especially given the increasing globalisation of learning through technology-related research is needed to investigate the implications, if any, of cultural differences.

Finally, we wish to reinforce the stance taken in this chapter that ILE should be applied in parallel with other learning whether at school or at home, and do not offer a replacement as sometimes advocated. Most ILE are designed to target particularly types of learning, give specific opportunities and (despite advances in the field of Artificial Intelligence) they are far from being able to replace any human teacher or tutor. Even when such systems are targeted at supporting group work, we believe that the social interaction with other students and the pedagogic support of a human teacher is fundamental to learning. However, what ILE are poised to do best, at least with the current state-of-the-art technology, is to reduce the mundane aspects of teaching and learning, provide opportunities for deliberate practice, and provide immediate feedback and ways to explore abstract concepts in concrete ways (e.g. through visualisations). Such opportunities can be augmented by the availability of data and analytics of learners’ real-time or retrospective interactions with the ILE in

[2]http://www.uis.unesco.org/Education/Pages/world-teachers-day-2015.aspx.

that they can support awareness and decision-making that is otherwise difficult to achieve if not impossible. This can free up time for the teachers to do what they do best—the essentially human aspects of teaching, including providing guidance and individualised support and motivating students to persevere with difficult concepts.

Glossary of Acronyms

Intelligent Learning Environments (ILE)
Intelligent Tutoring Systems (ITS)
Artificial Intelligence in Education (AIED)
Learning Analytics (LA)
Feedback–Reasoning–Analysis–Model/Events approach to design (FRAME)

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Chapter 5
Virtual and Cyber-Physical STEM Labs

Janusz Zalewski, Charles Xiaoxue Wang, Robert Kenny and Michele Stork

5.1 Introduction

The use of laboratories in academia dates back for many centuries with a purpose of conducting experiments or proving theoretical knowledge. Prior to the early 1900s, laboratories were mainly a territory of the natural sciences. This gradually shifted to include usage by the social sciences whereby education, psychology, and public health began to be studied in an experimental setting (Stadtlander, Giles & Sickel, 2013). Today, the laboratory is considered as an indispensable part of the learning environment in many fields of study where students work to construct their knowledge, enhance their professional and collaborative skills, and nurture their professional attitudes while stimulating interests and enjoyments and motivating students to learn (Špernjak & Šorgo, 2018). The fast development of Internet-related technologies in recent decades has increased the development of and hence uses of virtual laboratories in education. Virtual laboratories have caught the attention of many researchers and educational practitioners. These virtual laboratories have been built up to assimilate laboratory experiments in a realistic fashion with the primary purpose of providing new and unique learning opportunities for students. Among these laboratories, the cyber-physical laboratory is one that offers web-based access to students with capabilities to manipulate objects in the physical laboratory (e.g., robots or 3D printer). This chapter first synthesizes relevant literature findings for designing and developing a cyber-physical laboratory and then shares the theoretical concepts of cyber-physical laboratories that enable students to manipulate learning objects (e.g., robots or 3D printer) and its implications for STEM education.

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5.2 Literature Review

5.2.1 Laboratory Functions in Learning and Instruction

Understanding functions of laboratories guides the efforts for designing new laboratories for learning and instruction. Historically, many scholars have made efforts to describe the instructional functions of laboratories and the examples below highlight just a few that have been well-referenced.

In engineering education, laboratory experience is an essential part of its curriculum. Walkington, Pemberton, and Eastwell (1994) believed that laboratories are unique learning environments with four major functions for practical work in engineering.

- *To support the learning of theory*: Laboratories are used to illustrate or demonstrate phenomena, to apply theory to real situations, to demonstrate the limitations of theory, and to interact with phenomena in authentic situations.
- *To develop a body of knowledge*: Laboratories are used to help students develop and construct specific knowledge about materials, devices, professional practice, specific equipment and techniques.
- *To develop a body of skills*: Laboratories are used to develop and enhance relevant skills for critical observation, interpretation and assessment, planning and organization and practical problem-solving.
- *To develop attitudes*: Laboratories are used to stimulate an interest for learning and to generate self-confidence in practical job performance.

In physics teacher education, Harms (2000) summarized similar instructional functions for laboratories from the American Association of Physics Teachers as follows:

- The Art of Experimentation;
- Experimental and Analytical Skills;
- Conceptual Learning;
- Understanding the Basis of Knowledge in Physics; and,
- Developing Collaborative Learning Skills.

In science education, Hofstein and Lunetta (2004) and Hofstein (2017) offered slightly different perspectives on laboratory functions by focusing on the goals that laboratories used to assist students to achieve. They believe laboratories are used for the following purposes:

- To facilitate learning scientific concepts;
- To enhance interest and motivation;
- To improve scientific-practical skills and problem-solving abilities;
- To nurture scientific habits of mind;
- To promote understanding of the nature of science;
- To provide experience in method of scientific inquiry and reasoning; and,
- To apply scientific knowledge to everyday life.

To sum up, laboratories have been widely used for learning and instruction in many fields of study. Laboratories may function slightly different from each other in different fields and they also may function differently within the same field when they take different forms such as physical laboratories versus virtual ones. However, when these laboratories are used in education, they share many functions in common:

- To facilitate learning of theory and construction of knowledge;
- To practice and develop professional skills;
- To enhance problem-solving competence through situated learning and collaboration; and,
- To nurture professional attitude and ethics.

5.2.2 *Virtual Laboratories*

Dormido Bencomo (2004) proposed two criteria that characterize the different modalities of available experimentation environments. First, according to the way resources are accessed for experimental purposes, they can be remote or local. Second, according to the physical nature of the lab, they can be simulated or real. Combining those criteria, four types of experimentation environments are described by Scholars (Heradio et al., 2016) as follows:

1. Local access-real resource. This combination represents traditional hands-on labs, where the student is in front of a computer connected to the real plant.
2. Local access-simulated resource. The whole environment is software and the experimentation interface works on a simulated, virtual and physically nonexistent resource, which together with the interface is part of the computer. This configuration could be defined as a mono-user virtual lab.
3. Remote access-real resource. Real plant equipment is accessed through the Internet. The user remotely operates and controls a real plant through an experimentation interface. This approach is named remote lab.
4. Remote access-simulated resource. This form of experimentation is similar to the one above, but replacing the physical system with a model. The student operates with the experimentation interface on a virtual system reached through the Internet. The basic difference is that several users can operate simultaneously with the same virtual system. As it is a simulated process, it can be instantiated to serve anyone who asks for it. Thus, we have a multiuser virtual lab (p. 14–15).

For virtual laboratories, German scholar, Harms, identified five categories based on the unique ways they are used for teaching and learning. According to Harms (2000), they are:

- *Simulation laboratory*: Virtual laboratory that takes a form of classical simulations, containing certain elements of laboratory experiments and is available locally;

- *Cyber laboratory*: Virtual laboratory that takes classical simulations and contains certain elements of laboratory experiments but is accessible on the web (online) and is available as JAVA-Applets (or accessible with plug-ins);
- *Virtual laboratory*: Virtual laboratory which uses simulations to attempt to represent laboratory experiments as closely as possible for learning and instruction;
- *Virtual Reality (VR) laboratory*: Virtual laboratory which uses simulations through virtual reality techniques; and,
- *Remote laboratory*: Virtual Laboratory that is Internet-based which conducts real experiments via the Internet.

Many scholars (Dermido Bencomo, 2004; Gravier, Fayolle, Bayard, Ates, & Lardon, 2008; Heradio et al., 2016) have pointed out well-recognized benefits that virtual laboratories have including the following:

- *Availability of 24/7*: Virtual laboratories can be used anywhere and at any time, which bridges the distance gap and saves student travel time to experiment site.
- *Providing constant link between experiments and theory*: Virtual laboratories afford enhanced learning because of extended learning time and efforts.
- *Observability*: Virtual laboratories offers laboratory sessions that can be watched by many people or even recorded.
- *Safety*: Virtual laboratories such as those built on Virtual Reality environments can be a better alternative to hands-on labs for dangerous experimentation.
- *Adaptation and personalization of the laboratory environment to students with disabilities*: For people with disabilities, virtual laboratories enable them to learn and conduct experiments in their own homes using an Internet connection.

When studying virtual laboratories, many scholars recognize the above benefits that work toward facilitation of learning. In commenting on the uses of virtual and remote laboratories, scholars made very clear that knowing how to use them is more important than knowing what they are. As Heradio and Associates put it:

> In remote labs, students handle actual physical apparatus and get real data from physical experiments, i.e., from the same type of experiments that would be run in hands-on labs. Hence, students learn about the complexities of the real world, e.g., dealing with measurement errors whose simulation is far from trivial (Toth, Morrow, & Ludvico, 2009; de Jong et al., 2013). Our belief is that virtual, remote and hands-on labs are not exclusive alternatives, but valuable educational resources that can be combined in one integral and complementary learning unit. Such belief is supported by experimental evidence, as the pre-post comparison study design performed by Zacharia (Zacharia, 2007), which showed that the combination of remote and virtual experimentation enhanced students' conceptual understanding more than the use of remote experimentation alone (Heradio et al., 2016, p.16).

With these identified benefits and coupled with the fast development of Internet-based technology, more virtual laboratories in different formats will be used in education.

5.3 From Embedded Systems to Cyber-Physical Systems to the Internet of Things: Consequences for STEM Education

STEM education relies on introducing awareness of Science, Technology, Engineering, and Mathematics, collectively called STEM, and teaching respective skills and knowledge that can enhance student competitiveness in the job market when they graduate. The central motivation in this approach is a widespread belief that STEM-focused education contributes to innovation in product development and therefore has a significant impact on strengthening the economy and making it more competitive globally (National Science Board, 2007).

In addressing this challenge, Florida Gulf Coast University's (FGCU) Software Engineering Department has developed in recent years a sophisticated undergraduate software engineering lab for use in embedded and cyber-physical systems and related project courses (Gonzalez & Zalewski, 2014; Zalewski & Gonzalez, 2014). As a result, a number of teaching modules have been put in place, with emphasis on developing complex systems, studying their properties, and providing web-based access to the lab.

With the evolution of the Internet and emergence of the Internet of Things (IoT), new issues come into place, which must be addressed in courses on Embedded Systems and Cyber-physical Systems. The following discussion investigates the extension of traditional courses of that sort, to meet the challenges of IoT technologies. It offers a hierarchical approach to designing and implementing respective curricula, with project emphasis.

As a foundation, there is a need to prepare students to understand the measurement and control aspects of embedded systems. Once the students have an understanding of measurement and control aspects, the networking element is introduced, in a course on Cyber-physical Systems. A respective project example is outlined next. Finally, given that the students acquired respective background in two lower level courses, the next stage involves actual IoT applications with the use of a cloud, which is presented in Sect. 5.4.

5.3.1 Embedded Computing in STEM

It has been argued that one of the key factors in STEM education should be the integration of all four disciplines, which can be accomplished via the use of student projects (Zalewski & Gonzalez, 2014). Such an integrated approach to STEM is very rarely seen in current teaching practices at the undergraduate college level (Bybee, 2013). In particular, math and technology disciplines can be viewed as the basis of respective activities, and science and engineering draw from the support of math and technology, developing respective concepts at the higher levels. In this view, science

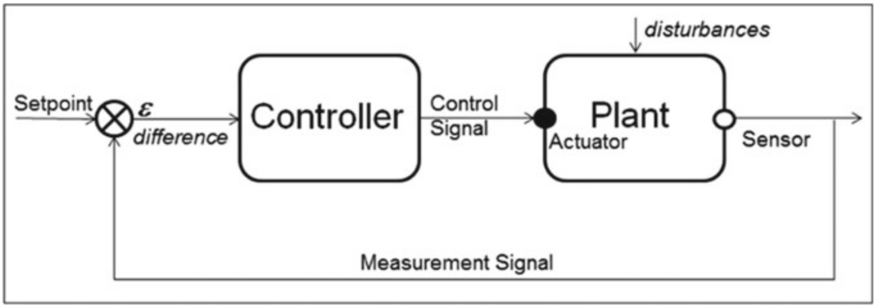

Fig. 5.1 Illustration of a feedback principle

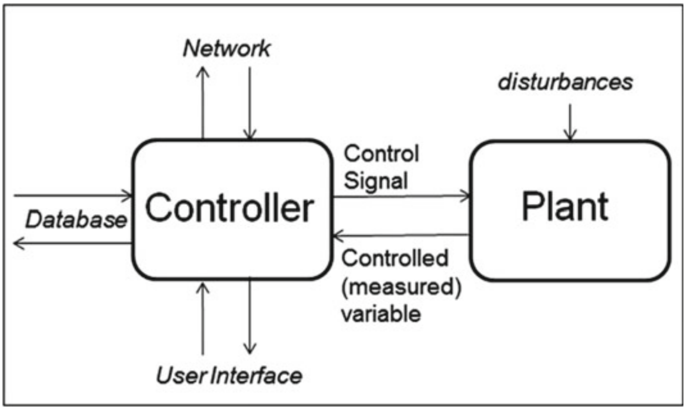

Fig. 5.2 Illustration of a modern embedded system

disciplines essentially rely on inquiry and discovery, while engineering activities apply scientific concepts to construction of respective artifacts.

As a fertile example, a concept of feedback control is used to illustrate the idea. The feedback principle, illustrated in Fig. 5.1, is one of the most fundamental concepts in nature and technology. In essence, every biological system, including a human being, exists due to the application of a feedback principle, which results in self-regulation. The same is true of social systems where self-regulation is essential to their survival and prosperity. In engineering, the first documented use of a feedback principle took place in the fourth century B.C., with the invention of a water clock. A more contemporary example would be a thermostat, which is a device operating on the very same principle of feedback control.

In contemporary applications, due to the development of technology, a simple control system expands into a more involved embedded system configuration, with interfaces to the user, the database and the network, as shown in Fig. 5.2.

5.3.2 Wearables

Specific kind of embedded devices are wearables, such as smartwatches, helmets, sewable microcontrollers, etc. They have I/O channels to contact the environment and some computing and wireless capabilities, making them suitable for all sorts of personal applications.

Wearable technology opens up a world of new possibilities because of the personalization that is achieved by being consistently physically connected to the device. Some examples include access to an individual's location with increased accuracy and biological data, such as heart rate or body temperature. This allows a device to keep a more accurate profile of an individual that cannot be realized by manually entering data into an app's profile section or within an approximation with an external object, such as a smartphone.

One specific wearable technology is focused on sports medicine to prevent injury and to compile personal stats reports. For example, Riddell's SpeedFlex helmet with InSite Impact Response System uses sensors to determine if an impact is a trauma risk and sends an alert if that impact exceeds the allowable limit. Another device of that sort is eyewear, such as Google Glass. At one point (Wu, Dameff, & Tully, 2014), Google Glass has been used to enhance simulation-based training of medical students and medical residents in a hospital setting.

5.3.3 The Google Glass

Google Glass is a wearable that was initially unveiled in 2012 at the Google I/O conference. The user is able to directly interact with the device through a combination of voice, touch, and head/facial movements. It is equipped with a 5-MP camera able to take photos and record videos in high definition 1280 $\times$ 720 resolution (720p), 1 GB of memory, and 16 GB persistent storage (Tang, 2014). A Google Glass can be controlled via the MyGlass application on an Android phone or tablet and communicated with via Bluetooth.

Although sales of the Google Glass in the Google Play store were discontinued early 2015, it is worthwhile to document a student project with this device as an example of developing skills for programming embedded devices.

One of these areas for potential wearable utilization is in the field of educational technology. The wearables may one day be as ubiquitous in the classroom as laptops and desktops but that is only if these devices manage to add value over traditional pedagogical methods. One application could be for learning simple algebraic operations, such as addition, subtraction, multiplication, and division. Points could be earned based on the number of correct answers and the length of time taken by the user.

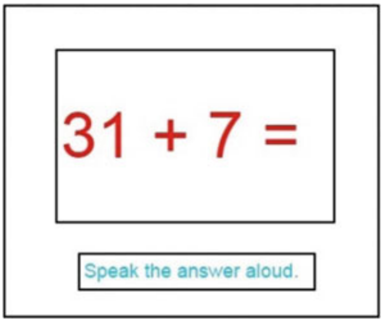

Fig. 5.3 Barebones sketch of Google Glass math app

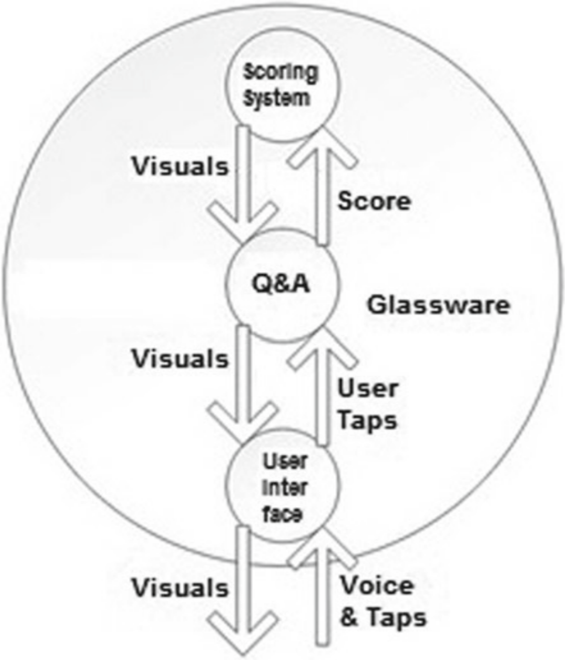

Fig. 5.4 Software architecture for the Math Glassware

The objective of a respective project was to explore educational technology applications for Google Glass, specifically as it relates to learning early math skills. A basic sketch of the addition mode of the application is shown in Fig. 5.3 and the software architecture is illustrated in Fig. 5.4.

5.4 Discussion: Cyber-Physical Systems in STEM

5.4.1 Emergence of the Discipline

With the ubiquity of the Internet, embedded systems have expanded into so-called cyber-physical systems, which offer not only direct connectivity with the physical environment but also networking of all interfaces illustrated in Fig. 5.2. This fact has been taken into account in education and publications started to appear documenting related courses (Shin, 2008; Marwedel, 2012), curriculum development (Lidström, Andersson, Bergh, Bjäde, & Mak, 2011), including textbooks (Lee & Seshia, 2012).

Examples of cyber-physical systems, such as modern software-intensive embedded systems, are applied in the most demanding real-time safety-critical applications, for instance, flight control, particle accelerator control, road vehicle control, etc. They are all distributed and for proper operation require very different programming techniques than traditional systems. Typical STEM curricula, however, rarely include respective methodologies of software development for such systems. Possible reasons for this situation include:

- difficulties with acquiring, operating and maintaining appropriate hardware and system software.
- necessity of acquiring specific knowledge of device architectures and low-level programming techniques for this hardware and system software, and
- need of significant attention to technical support, rarely available at the school or college level.

5.4.2 3D Printer as an Example of a Cyber-Physical System

3D printing has sparked somewhat of a modern-day industrial revolution. With its wide variety of applications that touch virtually every industry, the interest in 3D printing is only rising. Prototyping, modeling, prosthetics, and plastic duplicating are just a few of the possibilities that 3D printers can bring to the average consumer today, and the same is true for their more industrial (and more capable) counterparts. In the past couple of years, more affordable 3D printers have become available to the public, and today there are countless brands, sizes, and printable materials that have flooded the market. The Tiko 3D printer is just one example of a product designed and marketed for the average consumer.

The need for this project arises from safety concerns as well as educational needs. While 3D printers are sophisticated machines, they function in environments not entirely suitable for the production of quality prints. Oftentimes, this is made apparent when a lengthy print job has been scheduled. While smaller prints may be finished in under half an hour, most prints usually take up much more time—too long for some-one to sit around and monitor. For that reason, networking and visually monitoring 3D printers for the purpose of remote control are necessary.

Prints may fail due to miscalibration, inconsistencies in temperature, or a host of other possible issues. Unless the printer has been stopped by the user, it will continue to run its code forcing it to continuously extrude material wastefully. This article addresses the issue of education and safety, using the Lulzbot TAZ 5 3D printer.

5.4.3 Networking a 3D Printer

The objective of a related project was to expand the user's ability to interact and to interface with the 3D printer. Specifically, the goal was to facilitate a remote (network) communication between the user and the 3D printer for the sake of safety and education. The user will be able to monitor active prints and remotely take action if it is necessary in order to terminate a print, to move the hot extruder end away from danger, or to shut down the hot extruder end and hotbed. The TAZ 5 can exceed temperatures of 240 °C for the extruder, and the hotbed alone can reach past 100 °C. The focus is on these main safety mechanisms, which are essential to the goal of the project.

While this specific 3D printer can function in an untethered configuration, the Raspberry Pi single-board computer has been used in order to facilitate the network connection for remote control. Figure 5.5 visualizes this relationship. The Pi works as the server tethering the printer as well as relaying live visual data to be accessible on the Internet via the Raspberry Pi's onboard Apache server. The outer server handles incoming Internet connection requests and tunnels them to the Raspberry Pi that is on its network.

Among the requirements for connecting the printer to the Internet were the following:

- The Raspberry Pi (RPS) shall be able to broadcast live images of the 3D printer on the network.
- The RPS shall be able to establish full connectivity to the 3D printer in order to provide full control of it through one of its compatible applications, which means the ability to:
  - move the extruder head motors.
  - terminate a print in progress.
  - shut off both the extruder and the hotbed.
- The RPS shall be able to accept a remote (LAN) connection to a user seeking to take full control of the printer.

There were also additional requirements on the Graphical User Interface (GUI). With this, the context diagram for software development is shown in Fig. 5.6.

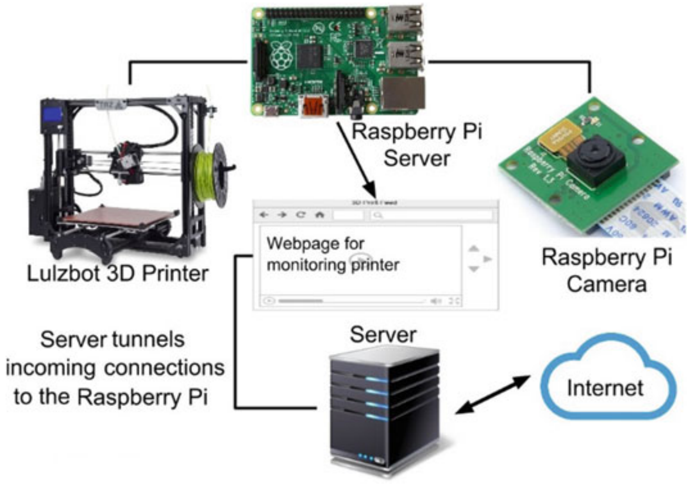

Fig. 5.5 Physical diagram of 3D printer connectivity

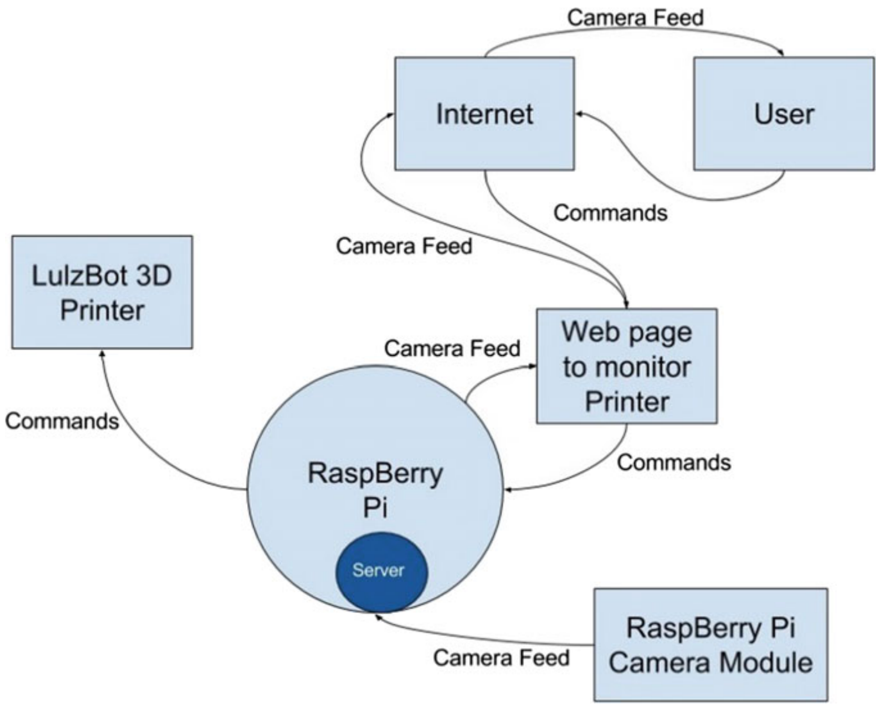

Fig. 5.6 Context diagram for software development

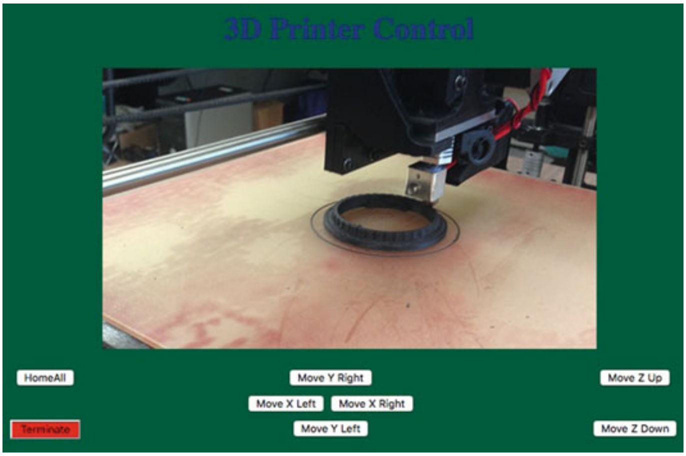

Fig. 5.7 GUI screenshot of live feed with print in progress

Following the requirements, the software for Raspberry Pi can be separated into four main functionalities: listening to user commands, sending commands to the 3D printer, packaging up the live camera feed, and finally, embedding the camera feed onto the web page for viewing. While the software development is too lengthy to be described here in more detail, the resulting GUI, as designed for remote user interaction, is shown in Fig. 5.7.

Although from its description the project looks like a sophisticated software engineering endeavor, in fact, it offers additional value for all STEM disciplines. For example: biological science and bioengineering—to teach shaping human and animal bones, technology—to teach principles of mechanical design, and math—to master solution of simple or more complicated equations mapped onto specific three-dimensional curves.

Practical exercises or experiments in any STEM discipline can be organized by starting with small demos, how to move the camera to observe the printer's operation, to more sophisticated, involving printer programming to perform specific tasks.

5.5 Internet of Things in STEM

5.5.1 The Emergence of Technology

Among new information technologies, the Internet of Things (IoT) is definitely making its way into teaching and learning (Marquez, Villanueva, Solarte, & Garcia, 2016), but there is very little experience or information how to use it effectively in education, especially, in STEM education. It is likely that the IoT is a disruptive technology in

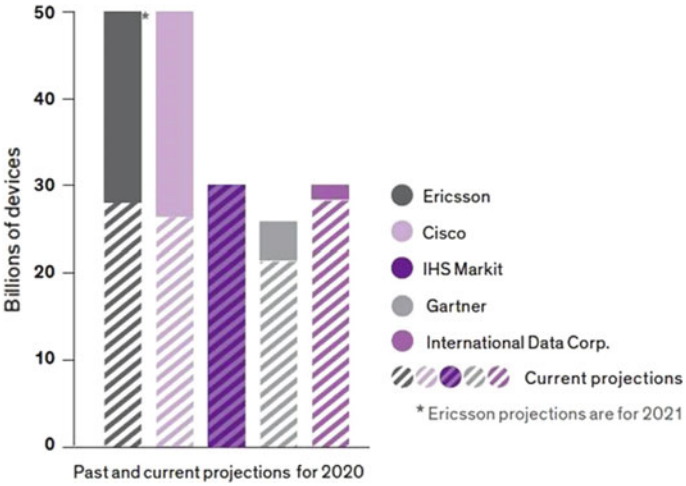

Fig. 5.8 Past and current projection for the number of interconnected devices (adopted from Selinger, Sepulveda, and Buchan (2013))

many industries and in business in general, but also in education. Actual numbers may vary by source but the consensus is that the volume of IoT connected devices will grow somewhat unpredictably to billions of units in the next decade, so will grow the market value, likely reaching trillions of dollars in the same period.

The early and later corrected predictions are both shown in Fig. 5.8. As summarized by Nordrum (2016), current estimates include the following numbers of devices by 2020:

- 28 billion, as corrected value by Ericsson (by 2021)
- 30 billion, corrected by former CISCO executive
- 30.7 billion by IHS Markit
- 28.1 billion by International Data Corp., and
- 30.7 billion in a study by Gartner.

Thus, it is clear that with numbers this big, education, including STEM education, will be heavily impacted. Therefore, given the pervasive nature of IoT it is necessary to address the educational aspects of the problem. Teaching how to design, implement and use the IoT is essential to all STEM professions.

5.5.2 The Principles of Technology

The IoT does not appear to have a single, widely adopted definition. However, the following definition should appeal more to the professionals since it comes from an engineering society (IEEE Standards Association, 2016):

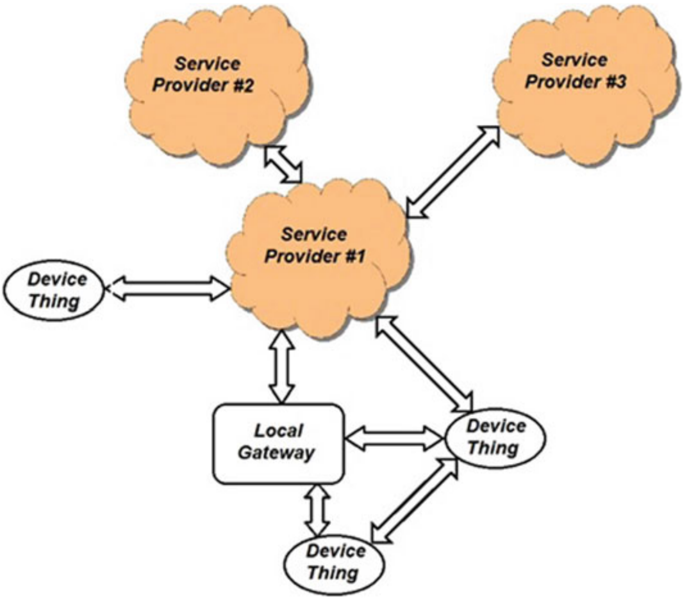

Fig. 5.9 Overall architecture of the Internet of Things

> Internet of Things (IoT) is a system consisting of networks of sensors, actuators, and smart objects whose purpose is to interconnect "all" things, including everyday and industrial objects, in such a way as to make them intelligent, programmable, and more capable of interacting with humans and each other.

There are a number of characteristics which can be attributed to the IoT. The most important ones are its architectural components, which can be listed as follows:

- smart devices at the user end;
- communication infrastructure for connectivity;
- computing cloud to provide data storage; and
- analytics tools at the cloud level.

As shown in Fig. 5.9, there are multiple devices ("things", some smart) at the user end, a communication infrastructure with devices accessing the cloud directly or via intermediaries, such as local gateways, and service providers in the cloud equipped with appropriate analytical tools. These are the critical constituents of the IoT, forming its architecture compliant with the one adopted by Intel Corporation (2016).

5.5.3 Overview of Using the IoT in Education

Prospects of using IoT in education, in general, are articulated the most vocally by computer companies, which sense a big business just around the corner. Such examples are Cisco Systems (Selinger, Sepulveda, & Buchan, 2013), and Intel Corporation (2015) which beyond hidden advertising provide valuable insight into the use of IoT in education. For example, Cisco Systems considers the following key factors for successful implementation of IoT in education: security, data integrity, and education policies (Selinger et al., 2013). Intel Corporation (2015) advocates that IoT has the potential to trigger enablers to create the "synthesizing mind" which include: programming (commonly understood as "coding"), science, and making (in a sense of "maker movement").

There is, however, an independent study by the British Computer Society (2013) which emphasizes the enormous significance of IoT in education for the future:

> The impact of the Internet of Things is likely to be revolutionary in all areas of education. This will be a consequence of speed of deployment, ubiquity, global scale, low cost and connectivity of billions of intelligent sensors and actuator devices generating unprecedentedly huge amounts of data. The interconnectivity and cutting across silos will place more demand on hybrid skills throughout ICT and beyond.

With respect of using IoT in higher education, the industry is definitely taking the lead. Most notably in a special issue of *Educause Review* (Asseo, Johnson, Nilsson, Chalapathy, & Costello, 2016) executives from Salesforce, Google, Extreme Networks, IBM and Cisco Systems present their views on the IoT impacts on higher education, followed by some sobering thoughts of one of the Information Technology directors at a major U.S. university:

> The IoT and IoT systems have the potential to provide substantial value to higher education institutions. But the implementation of those systems creates seams with our existing IT and information management ecosystems.

The academic research falls far behind the industry and there are only a handful of studies analyzing impacts of IoT on higher education in the forthcoming years. In one paper (Zhang, 2012), a number of changes that educators and administrators will face due to the introduction of IoT are listed, including: changes in teaching and learning, experimental and practical changes, need for a change in management, etc.

In another article, Veeramanickam and Mohanapriya (2016) focus on presenting the needs for adopting IoT technology on campus in e-learning, calling it smart *i-campus*. It points to a number of issues facing those who implement the *i-campus*s related mostly to the use of new technologies but omitting completely the changes in pedagogy resulting from adopting the new approach. Elsewhere, Bogdanovic, Simic, Milutinovic, Radenkovic, and Despotovic-Zrakic (2014) present academic experiences on learning the IoT technology for purposes of e-business courses. The described model relies on using cheap, general-purpose boards based on Raspberry Pi and Arduino microcontrollers. The authors outline the course structure and its pilot implementation, sharing their first experiences and feedback from students.

The use of IoT in engineering education and specific impacts on this area are highlighted in the presentation done at *International Conference on e-Technologies in Engineering Education* in Gdansk, Poland (Gonzalez, Guo, Nowicki, & Zalewski, 2017).

Fig. 5.10 Connectivity of the smartwatch with Android and cloud

5.5.4 Remote Health Monitoring

The Software Engineering program at the authors' institution aims at creating a full IoT specialization. For the time being prospective specialization courses have been defined and are in the process of approval. They are all project-based, of which one is described here. Each project has a small embedded device, sensor or/and actuator, and targets a specific cloud platform. The choice of both the device and the platform is given to students with instructor's approval.

The specific project involves using a Moto 360 smartwatch to implement a person's monitoring health parameters for use by a doctor and a person themselves. Initially only one parameter, heart rate, was measured, but a completely operational system was implemented with full connectivity to a Google Cloud, as shown in Fig. 5.10.

For STEM education it is essential to demonstrate in each project a practical usefulness, which in terms of the designs means usability, as illustrated in Fig. 5.11. By reading the user's heart rate and sending the data via smartphone to the health monitoring server, which stores the history of all the information it receives, the application allows a doctor and a patient to stay in touch over a secure network regarding all actions necessary to monitor health.

5.6 Summary and Conclusion

This chapter has described a progressive way of developing virtual online labs by using student projects in teaching courses on embedded systems through cyber-physical systems through the Internet of Things, with application in STEM disciplines. Future schools will benefit from the use of simple embedded devices, such as

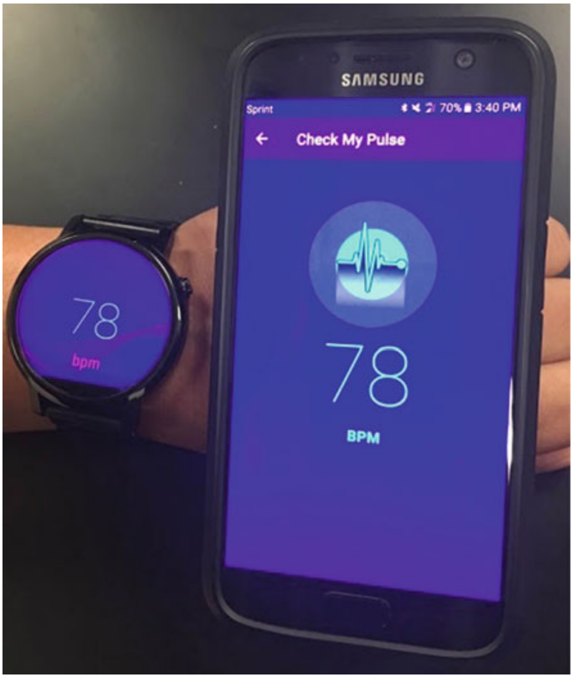

Fig. 5.11 Practical usefulness of the smartwatch solution

a temperature controller, to much more involved but still at this level such as a Google Glass, in which every STEM discipline can find interesting examples of applications matching student interests. The situation gets more complicated with the use of the Internet, which leads to expanding the projects to cyber-physical systems and the IoT; however, many of the reported experiments have been found to fit the specifics of respective STEM disciplines and enhance the instruction with digital technologies.

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Chapter 6
Supporting Student Learning Toward Twenty-First-Century Skills Through Digital Storytelling

Hannele Niemi, Shuanghong Jenny Niu, BaoPing Li and Marianna Vivitsou

6.1 Introduction

6.1.1 Changing Learning and Teaching Environments

The concept of learning has gone through a multilayered process of redefinition in recent years. Academically, it is typically regarded as an active process, whereby learners construct their own knowledge base. Learning is also increasingly viewed as a process that is based on sharing and participation with different partners in a community, and as a holistic constructing process that is interconnected with learners' emotional, social, and cultural premises (Cole, 1991; Salomon, 1993; Cole & Cigagas, 2010; Niemi, 2009; Säljö, 2010, 2012; Hakkarainen, Paavola, Kangas, & Seitamaa-Hakkarainen, 2013). The concept of "life-long learning" is more of a life-course process.

We learn in different situations and areas of life that are cross-boundary. Learning and knowledge are no longer the monopolistic domains of schools, or even univer-

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sities. In our modern societies, there are many forums of learning, which may be called *learning spaces*. Working life and work organizations are important learning spaces (Nonaka & Konno, 1998; Nonaka & Takeuchi, 1995; Nonaka & Toyama, 2003). Technology-enriched learning tools and spaces with mobile technology, social media, and all existing digital resources create a powerful arena for learning, both in formal and informal education settings.

Our learning is life-wide, and consists of vertical life-course learning, as well as horizontal dimensions. This means that there are continuous processes of learning: vertically, throughout various ages, and horizontally, in cross-boundary spaces of life (Niemi, 2003). Learning is not limited to certain ages or institutions. Learning exists in every moment and every situation if we become aware of the learning and reflect on the learning.

These changes in the way learning take place are the consequence of worldwide megatrends that have unleashed sweeping changes with ongoing innovations with digital technologies and communications.

6.2 Twenty-First-Century Skills as the Aim of Educational Systems

The way to prepare a new generation for the future, its working life, and life-wide learning has become an urgent topic on the agenda of educational systems (e.g., Binkley et al., 2012). The European Union (2006) has defined the eight core competencies for lifelong learning, and the Organization for Economic Co-operation and Development as well as many global organizations have identified necessary twenty-first-century skills (Griffin 2013; Griffin, McGaw, & Care, 2013). While there is some variation, the most important message is that schools must seek new forms of teaching and learning. Many discussions and documents have proposed ways to face the future, and have delineated the roles of schools and teachers in these changing contexts (e.g., Bellanca & Brandt, 2010; Griffin et al. 2012).

> Andreas Schleicher (2012) argued that "Everyone realises that the skills that are easiest to teach and easiest to test are now also the skills that are easiest to automate, digitise and outsource. Of ever-growing importance, but so much harder to develop, are ways of thinking - creativity, critical thinking, problem-solving, decision-making and learning; ways of working – including communication and collaboration; and tools for working – including information and communications technologies".

Although definitions of twenty-first-century skills vary, there are some commonalities. The most important factors are:

- Students should have the capacity to learn throughout their lives, and that education should provide the skills and mental tools to enable them to do so.
- Inquiry and knowledge-creation abilities are important, but they should be connected with analytical and critical thinking skills, as well as creativity.

- Students should have the capability to ask questions, and not simply seek or repeat ready answers. They need the ability to work independently, but also, increasingly, collaboratively. Life is ever more bound up with technology; learning environments are continuously changing, and ICT provides many new learning opportunities.

Working life is also changing dramatically. Increased global interconnectivity puts diversity and adaptability at the center of organizational operations. Workplace robotics nudges human workers out of rote, repetitive tasks, and new media ecology requires new literacies. Davies, Fidler, and Gorbis (2011) summarized that skills and abilities related to higher level thinking, and social relationships that cannot be easily transferred to machines, will enable us to create unique insights and be critical to decision-making. Workers will require social skills that enable them to collaborate and build relationships of trust locally, as well as globally. Workers must also be capable of responding to unique, unexpected circumstances that may occur at any moment (Autor, 2010). Jones, Valdez, Nowakowski, and Rasmussen (1994) suggested that successful, engaged learners are responsible for their own learning. These students are self-regulated, and are capable of defining their own learning goals, and evaluating their own achievements. They are also energized by their learning; their joy in learning leads to a lifelong passion for solving problems, understanding, and taking the next step in their thinking. These learners are strategic, in that they know how to learn and are capable of transferring knowledge to solve problems creatively. Engaged learning also involves being collaborative, that is, valuing and having the skills to work with others.

Taylor and Parsons (2011) analyzed what student engagement might be. They introduced several types of engagement: academic, cognitive, intellectual, institutional, emotional, behavioral, social, and psychological. After exploring numerous definitions, they concluded that the following criteria characterize engagement:

- Learning that is relevant, real, and intentionally interdisciplinary, at times moving learning from the classroom into the community.
- Technology-rich learning environments, not just computers, but all types of technology, including scientific equipment, multimedia resources, industrial technology, and diverse forms of portable communication technology.
- Learning environments that are positive, challenging, and open, sometimes called "transparent" learning climates, encourage risk-taking and guide learners toward co-articulated high expectations. Students are involved in assessment for, and of, learning.
- Collaboration via respectful "peer-to-peer" type relationships between students and teachers.

6.3 Digital Storytelling as a Pedagogical Method

6.3.1 What Is Digital Storytelling?

According to Jenkins, Purushotma, Weigel, Clinton, and Robinson (2009), Digital Storytelling (DST) is one mode of twenty-first-century learning. As a pedagogical method, DST builds on learner-centered approaches (Kearney, 2009; Yang & Wu, 2012) and it allows teacher practices and students' learning to meet the needs and requirements of twenty-first-century skills. Robin (2008) proposed that DST takes advantage of the creative potential of modern communication technologies. Students are encouraged to become creators, producers, and discussants, rather than simply passive audience members. DST allows students to work collaboratively in groups, plan the task at hand, implement and evaluate the stories as products. Figure 6.1 shows the process of conducting Digital Storytelling as pedagogical method.

According to Niemi et al. (2014), learning with DST is seen as a socially and culturally related process that takes place in the interaction between a learner and material tools, psychological tools, or other human beings (Vygotsky, 1978). Learners play a central role in exploring and building knowledge by using tools available in the digital learning environment. When planning, and making digital stories collaboratively, students can become aware of their own knowledge and experiences and reflect on and share these experiences with others. Watching other students' stories can also create new perspectives on topics and promote the understanding of a certain phenomenon (Niemi et al., 2014).

DST pedagogy draws from learner-centered approaches that aim to enable student learning through the use of connective technologies, digital mobile devices, and language toward the production of meaningful stories (McGee, 2015). The aim

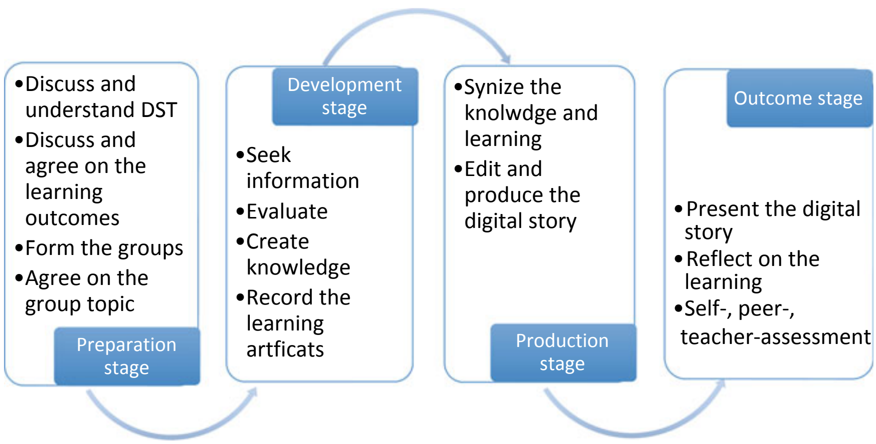


Fig. 6.1 The process and steps of DST as a pedagogical method

of this educational method (McGee, 2015) is to give pupils a chance to tell their own stories about the topic under discussion. The method highlights a do-it-yourself attitude, participatory practice, and constructive creative elements in creating the story; increases engagement on the topic; is collaborative; encourages active participation; blurs the roles of the learner and the instructor; and encourages shared learning and creativity (Lambert, 2013; McGee, 2015; Niemi et al., 2014; Sadik, 2008; Shelby-Caffey, Úbéda, & Jenkins, 2014; Sukovic, 2014; Woodhouse, 2008).

When designing, shooting, and evaluating the videos, the students acquire knowledge that is related to their video topics. Glynda Hull's extensive experience of using digital storytelling among young people from different cultural contexts and in danger of dropping out provides evidence that sharing experiences through student-driven videos is a highly empowering tool (Hull & Katz, 2006; Hull, Kenney, Marple, & Forsman-Schneider, 2006; Hull, Zacher, & Hibbert, 2009). In addition, Robin (2008) suggested that digital storytelling takes advantage of the creative potential of modern communication technologies. In this way, students are encouraged to become creators, producers, and discussants, rather than simply passive audience members.

Table 6.1 presents the types of stories that emerged from the analysis of content and mode of production in earlier studies (Vivitsou, Kallunki, Niemi, Penttilä, & Harju, 2016) in relation to subject-based or integrated teaching approaches. It should be noted, however, that the categories are neither mutually exclusive nor compact.

As the table shows, stories could be focused on a single event or on longer descriptions as a series of events. Students also created both subject-specific and interdisciplinary stories. The latter often featured a more structured narrative by recounting multiple events. In their stories, for example, students used "real-life" characters as a

Table 6.1 Types of digital stories (Vivitsou et al., 2016)

	Single stories	Multiple event stories
Subject-based digital stories	Instances of a phenomenon • Chemical reaction	Multiple-phenomenon based stories • Science subjects: water, motion, air • Humanistic subjects: historical events, biographies, language topics
Interdisciplinary digital stories	Instances of an interdisciplinary phenomenon • One event in a forest on a field trip	Theme-based stories • Recycling • Well-being • Myths • Animal testing
Student-initiated stories	Introducing myself and my class to peers	Instances from everyday life • Hobbies • My friends • Ethical issues • Citizenship

peer or as a narrator, while in others they used fictional characters to pull the narrative together and convey the message.

In DST students are responsible for their own learning process and learning outcomes with the support from teachers. The role of teachers also changes in this pedagogical approach. The teachers are no longer in the center of the classroom. The students are in the center of the stage, and the teachers are at the side. The classroom is filled with students' voice, not with teachers' speeches. However, it is not only the students who take up a more active role in the pedagogical process, but the teachers also need to adapt their teaching practices in order to successfully meet the requirements of the new situation. Therefore, the teachers' role changes as well.

6.3.2 Toward Global Sharing Pedagogy

The Finnish research project *Finnable 2020* has drafted a model of the Global Sharing Pedagogy (GSP) for promoting twenty-first-century skills in schools with digital storytelling (Niemi et al., 2014; Niemi & Multisilta, 2016) (see Fig. 6.2). The aim has been to connect megatrends of changes in learning concepts, knowledge creation, and working life with teaching and learning. The GSP is based on sociocultural theories where learning is viewed as a result of dialogical interactions between people, substances, and artifacts (Pea, 2004; Cole & Cigagas, 2010; Säljö, 2012; Hakkarainen et al. 2013). The primary objective is to strengthen student engagement in learning and mediate students as they become active learners and knowledge creators in changes they are facing already, and will increasingly face in their future. However, engagement is not viewed only as an end. It is also a means for further learning. It is regarded as a motivational component that consists of the emotional states of students, such as the joy and fun experienced in learning, as well as qualities that are typical of self-regulated learning. It includes a commitment to learning tasks, and a willingness to make efforts to achieve an objective (Pintrich & Ruohotie, 2000; Pintrich & McKeachie, 2000).

Learner-driven knowledge and skills creation is an objective that provides learners with symbolic tools for the development of active learning methods and metacognitive skills. This is a dynamic process in which learners, guided by reflection and metacognition, manage their thinking and learning resources. Learners require strategic skills to manage their own learning and create new knowledge, both individually and collaboratively (Pintrich & McKeachie, 2000; Nevgi, Virtanen, & Niemi, 2006). Schools and teachers should encourage students to engage in this type of independent learning (Niemi, 2002; Scardamalia, 2002; Scardamalia & Bereiter, 2003). Learning affects students cognitively, emotionally, socially, and morally, and the more independent and self-regulating students are, the more they must also be aware of, and employ, ethics and values. Mediation toward student-driven knowledge creation consists of different kinds of symbolic tools, such as critical thinking, creativity, argumentation, "learning to learn" skills, and ethics and values.

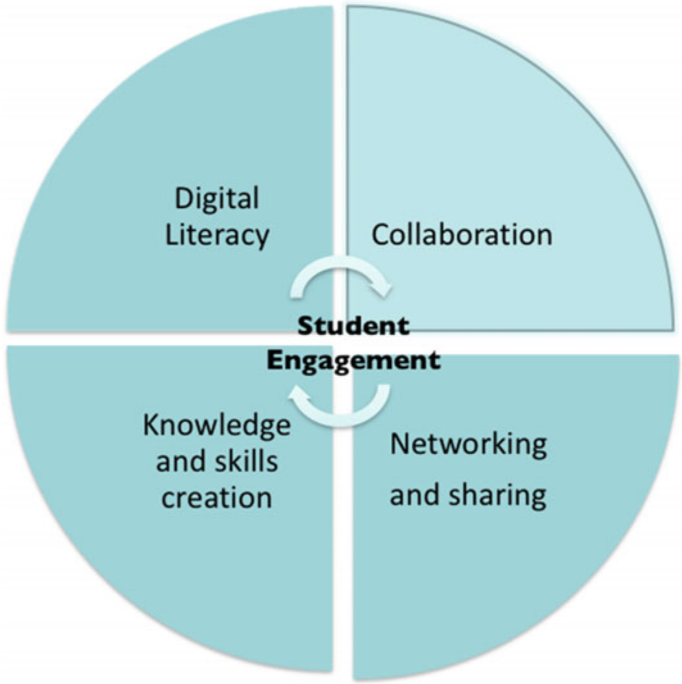


Fig. 6.2 The components of global sharing pedagogy

Collaboration is a social objective that allows or requires students to work together (Hull, Zacher, & Hibbert, 2009; Pea & Lindgren, 2008; Rogoff, 1990; Wells, 1999). It ensures that they can learn and work in the global world in the future; they must develop the following competencies beyond the purely "cognitive": social skills, cultural literacy and understanding, help-seeking, and help-giving strategies.

Networking is also a social objective that uses synergy of expertise of other people and also provides tools for intercultural learning (Starke-Meyerring, Duin, & Palvetzian, 2007; Starke-Meyerring & Wilson, 2008). In distributed cognitions and interaction with different artifacts, people introduce remarkable value that enhances their learning and competencies. These processes are mutually constitutive. All learners are also contributors. Thus, networking means sharing learning from others, as well as sharing ideas and experiences.

Digital media competencies and literacies is an objective that enriches learning through new technology environments, but it can also consist of social and symbolic mediators through different kinds of digital environments (Säljö, 2010, 2012). In technological environments, learners are both content producers and consumers. As such, they need the skills to study and work in digital environments. They must also critically assess and validate the knowledge they find and create; they must be accountable to the norms of discourse and argumentation established by the adult communities of practice in each discipline. They also require skills in the creation and discussion of social media, and in promoting ethical behavior in these media environments. Mediation of digital media competencies and literacy consists of the following skills that schools should provide to students: content creation, with critical content interpretations and validation, and social media skills that are part of digital environments.

6.4 Three Case Studies of Learning with DST

6.4.1 Digital Stories Across Countries

In a related study, we introduce how digital storytelling can create virtual learning environments when it is used for learning twenty-first-century skills and competencies needed in students' future working life (Niemi et al., 2014; Niemi & Multisilta, 2016). The study describes how students (n = 319) in three countries and their teachers (n = 28) value digital storytelling and what they think students have learned. Their experiences are analyzed using a theoretical conceptualization of the global sharing pedagogy that sets categories of processes or tools as objectives: (1) learner-driven knowledge and skills creation, (2) collaboration, (3) networking, and (4) digital literacy. Analyses have been quantitative and qualitative. The study describes students' experiences when they created their digital stories and how they engaged in learning.

Data was collected between September and November 2012. The participating students were in elementary, lower, and upper secondary schools in three countries: Finland, the USA (California), and Greece. The total number of students-participants was 319, with a balanced gender distribution of 159 girls and 160 boys. Most students were between 10 and 14 years old. The students created over 1000 videos altogether. Most of them were between 2 and 4 min in length. Schools and teachers had the freedom to choose how they wanted to use DST in their teaching.

Stories included language learning, physics, chemistry, biology, and history. In some classes, the topics were multidisciplinary. They could combine, for example, traffic education, language learning, and art in the topic. Video stories could also work as educational videos, where students taught other students to do something. This happened in one second-grade class; students made video stories in their teddy bear project, where they taught other students how to make different handicrafts.

The major findings are that students enjoyed creating their stories, and they were very engaged in their work. They learned many twenty-first-century skills when creating their digital stories. The findings strongly support that learning with DST method has powerful effect on students' motivation and enthusiasm, including both fun and commitment to hard work. This study shows that students enjoy creating digital stories, and they are engaged in school work. However, they need more skills in collaboration, opportunities for networking, and teachers' guidance in knowledge creation and digital competencies.

6.4.2 Video Inquiry Project: STEM Learning and Teaching with DST

The second project was established in 2013 and involved the collaboration among Stanford University, Helsinki University, University of Lapland, and Pepperdine University (Penttilä, Kallunki, Niemi, & Multisilta, 2016). The "Video Inquiry Project: STEM Learning and Teaching with Mobile Video Inquiries and Communities" (2013–2015) aimed to seek innovative tools and research findings to support new pedagogical models that simultaneously foster learners' and teachers' interests in and joint attention to the power of science and mathematics in explaining phenomena "in the everyday world".

The students created short video stories collaboratively in this project too. Having designed, captured, and edited the stories, students shared their work with peers online (Vivitsou et al., 2017; Penttilä et al., 2016). One topic was: *motion.* The learning objectives focused mainly on the ability to identify and classify different types of motion, such as linear, curvilinear, and constant, and also to qualitatively understand the concepts of velocity, acceleration, and force.

Based on the digital stories, students' epistemic thinking about the phenomenon of motion widened during the learning period from everyday-like to more scientific. For instance, in their orientation videos students often equated motion to the physical activity of human beings. Thus, they filmed each other while doing different kinds of exercises (e.g., walking, jumping, doing cartwheels, etc.). Eventually, the videos that only a few had captured from inanimate objects (e.g., a helicopter flying in the sky) ended up being of importance in helping the students to see motion from a broader perspective, implying an ability to observe motion everywhere in their surroundings as one of the students stated in the final interview:

> I'd say that motion can be observed just about anywhere.

This broader understanding also included definitions of different kinds of motion phenomena. For example, in their digital stories the students were able to define the motion of a rollercoaster ride as curvilinear, or of a bus leaving from a bus stop as an accelerating motion.

The second topic was: *air*. During a visit to a science center where students were exploring the theme of air, was an exhibition of a hot air balloon. In the exhibition, the balloon was rising and falling depending on air temperature, while the temperature was observable from a thermometer placed close to the landing spot of the balloon. While observing this process and listening to the guide explaining its causes and effects, students familiarized with the mechanisms of how a hot air balloon works and used this information in their stories to highlight the key points such as "air requires space" and "warm air rises and expands". In this sense, students also considered their digital stories as image-based notes of their observations and found them useful in enhancing their memory.

Working with teachers by employing design-based research methodology, they established a web-based community platform for uploading short-form STEM-related videos and associated inquiry questions developed by participating learners and teachers, and develop scaffolding and social media functions for making reflective connections from these video resources to curriculum topics and classroom activities.

The immense quantity of video resulting from digital video cameras everywhere was making video ubiquitous as a cultural medium and in principle, as a scientific medium for STEM educational purposes. This project conducted design-based research and development to establish a broadly scalable approach for students and teachers to capture standard and video recordings of events and phenomena that spark questions for them that can serve as seeds for inquiries in the STEM disciplines.

6.4.3 Learning Math and Twenty-First-Century Competences with DST

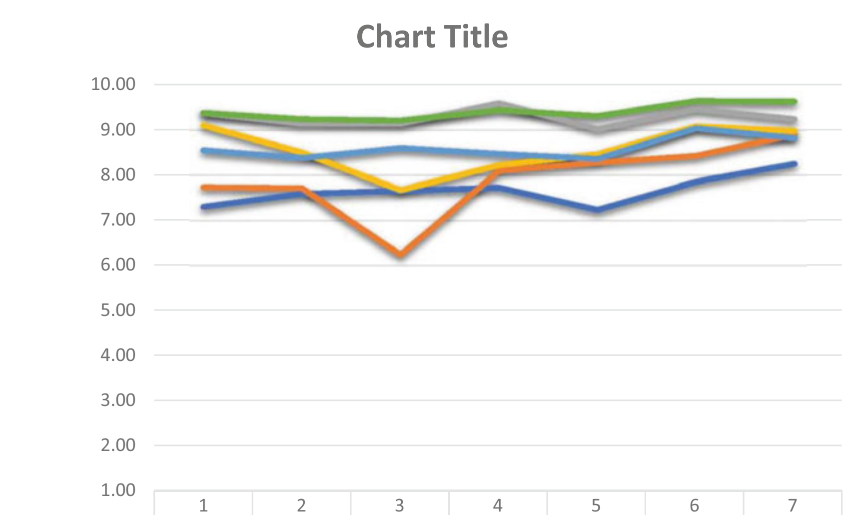
In 2016, University of Helsinki and Beijing Normal University initiated a joint project focused on how students can learn twenty-first-century competences in math learning. The project was part of the *Future School 2030* project led by the Advanced Innovation Center for Future Education (AICFE) at Beijing Normal University.

The theme focused on calculating the area size of 3 different geometry shapes. However, the pedagogical course design was also multidisciplinary. Math learning with Digital Storytelling (DST) required the students to seek and learn various knowledge and skills. In order to produce the digital story in math learning, the students also needed to learn language, visual arts, music, and computer software. This required collaboration among teachers and principals, parents and friends. In this way, a collaborative learning community was created.

When starting the project, the teachers explained to the students what the DST method and discussed with students what the main elements, processes, and learning outcomes in doing DST are. The participating students were 4th and 5th graders, 10–11-year-old young adolescents in primary school in Beijing in China and in Helsinki in Finland. Four classes from China were involved in this research, a total of 135 students. In Finland, there were two classes with a total of 49 students.

Learning mathematics involves developing abstract thinking, in addition to handling a series of complex mathematical concepts. In many schools, both in Finland and China, teaching math remains teacher-centered and usually of a "stage-on-the-stage" type. The project was interested to look into how a student-centered, collaboration-oriented approach allows for deeper and wider student engagement. The data was collected through pre-questionnaires, daily questionnaires, post-questionnaires, observations, and interviews with students and teachers.

The analysis of the students' questionnaire evaluation and the students' and teachers' interviews indicates that DST can promote learning math in schools and well as twenty-first-century skills. The skills that were chosen to be measured were based on the components of Global Sharing Pedagogy: *Knowledge creation, Collabora-*



	1	2	3	4	5	6	7
Series1	7.30	7.59	7.66	7.73	7.23	7.86	8.25
Series2	7.74	7.72	6.24	8.10	8.28	8.43	8.90
Series3	9.38	9.14	9.14	9.59	9.02	9.46	9.24
Series4	9.1	8.5	7.67	8.22	8.46	9.08	8.98
Series5	8.55	8.38	8.6	8.47	8.36	9.04	8.82
Series6	9.38	9.24	9.21	9.44	9.31	9.64	9.63

Fig. 6.3 Students' self-evaluations about their learning in DST project in Finland and China

tion, Networking with Knowledge sharing and Digital competences. Figure 6.3 illustrates how DST has promoted students' learning successfully in this project. It also describes that students' engagement has been very high. They have been very motivated to work hard and they have enjoyed learning (Niemi, Niu, Vivitsou, & Li, 2018).

Finnish classrooms (total 49 students): Series 1–2; Chinese classrooms (total 135 students): series 3–6.

I learned the following things during the storytelling project. Evaluate according to your own opinion how accurately the following statements describe you. The scale is: (Not at all) 1, …, 10 (very much) (Niemi et al., 2018).

1. I learned new knowledge about math
2. I learned how math relates to everyday life
3. I learned new skills such as recording and editing videos, finding new information from books or the Internet, etc.
4. I learned how to work in a group with my classmates
5. I gained new ideas from my peers
6. In my opinion, it was fun to do tasks that relate to digital storytelling
7. I worked hard during the lesson/phase of work

The main conclusions of this research project are:

- Learning math with DST can increase students' motivation and engagement;
- DST pedagogical method can support students' learning toward twenty-first-century skills;
- Students enjoyed this learning method,
- Students need more support in technical issues of video creation.

6.5 Discussions and Conclusions

Robin (2008) stated that students can get benefits when they are given the task of creating their own digital stories. This creative work provides students with a strong foundation in what many educators have begun calling twenty-first-century skills. Students can develop enhanced communication skills as they learn to conduct research on a topic, ask questions, organize their ideas, express opinions, and construct meaningful narratives. In Blas (2016) large-scale digital storytelling initiative, students can increase their knowledge through interacting with external institutions, experts, instructors, and peers, raise the learning interest and foster the communication skills and media literacy. DST fosters collaboration and co-construction of meaning.

The key elements of the DST pedagogical method are collaborative work during the whole project. Students work in small groups to search and analyze information, and to create the knowledge and digital story together. There are lots of interactions among students themselves and with teachers while making the digital story. The students gradually learn how to express themselves, how to discuss with others, how to negotiate, how to influence others, and how to contribute in teamwork. In our students' interviews, almost every student highlighted the group work collaboration, and how they have achieved agreement when there are different opinions and ideas. Based on our three case studies, students' communication skills and collaboration skills have been greatly developed while conducting DST learning.

Cultural competence, interaction, and expression are essential parts of DST because everything happens in groups, and many themes of the video products can focus on wide societal, cultural, and ethical themes (e.g., recycling, homelessness, and animal testing). The work of the DST projects can also be related to many themes that promote managing daily life and taking care of oneself and others.

Because students learn recording, editing, mixing, and applying various information sources, they also learn multi-literacy in the context of multimodality, where digital and traditional literacies are connected and integrated with ICT-competence. DST connects formal and informal learning settings by crossing borders in knowledge creation. Traditionally, a story needs a beginning, a middle and an end to be considered a story. Nowadays, however, more avant-garde views question the triple feature and allow for less fixed definitions. Stories can recount a single event or an array of events. Given this, and taking into consideration that telling a story is not attached to one mode of expression (e.g., oral or written speech only), we can say that the use of the term is rather metaphorical nowadays. Although "storytelling" used to be associated with oral expression, it now refers to a variety of modes of fixation and inscription (e.g., writing, acting out a role, filming, etc.).

According to Stewart and Gachago's (2016) study, DST can be used to facilitate an engagement across borders/continents with differently positioned students. Also, there is evidence suggesting that the method encourages active participation as well as shared learning and creativity (Lambert, 2013; McGee, 2015; Niemi et al., 2014; Sadik, 2008; Shelby-Caffey et al. 2014; Sukovic, 2014; Woodhouse, 2008). Digital storytelling, therefore, is one way to increase engagement in school learning (Niemi & Multisilta 2016). In storytelling projects students work collaboratively in technology-rich environments by sharing their ideas. They inquire and create new knowledge by learning from each other and assess their learning processes and products.

There are also some challenges in doing DST. One of the main challenges is time. Student-centered learning with DST pedagogical method may take longer time than the normal lecture hours in the beginning when teachers and students are not familiar with this method. However, we need to remember that students are not only learning content knowledge, but also skills and competences. Developing skills and competences needs time and continuous practice. Therefore, schools and teachers need to prepare enough time in the beginning when starting using the DST method. Once teachers and students become familiar with the method, it will be more and more easy and less time consuming. Therefore, the curriculum must be flexible. And over time the students will gain more skills and competences which they need now and specially in the future with continuous practice and development.

Another issue that requires further attention is how to evaluate student-generated digital stories. In the three cases discussed above, the evaluation of digital storytelling activities served both research and pedagogical purposes. As mentioned previously, questionnaires, field observations, and interviews were used for research. In addition, for pedagogy, students reflected on the process and exchanged views in groups. Students also gave feedback to their peers' videos. This type of self- and peer-evaluation is consistent with learner-centered approaches that make room for students to develop awareness of the process and grow into more autonomous learners by, for example, setting objectives, revise the learning plan and regulate their progress. In this way, evaluation can contribute to the improvement of operational processes and the quality of learning outcomes that related to twenty-first-century competences (Harju & Niemi, 2017). Self-evaluation, peer evaluation, and supportive formative evaluation are important methods targeting a holistic approach and a deeper understanding of student development, along with a broader view into what the learning progress looks like.

In all cases, the common feature was that students would need more criteria on how they can evaluate their own and peers' products. They need more awareness about the aims and what constitute quality criteria, e.g., how a good story takes audience into consideration, how contents are introduced and argued, and how different learners participated in collaboration. Criteria could allow young students form a concrete understanding of related constructs (e.g., the narrative and associated meanings, relevant concepts, and so on) and, thus, develop a meta-awareness of telling and sharing digital stories.

In digital storytelling, the knowledge building factor relates to subject-matter and how well the student grasps the object (or content) of study. For instance, if the content is about geometrical shapes (e.g., triangles), the digital story should present relevant thematic dimensions, concepts and terms, and organize and present them in a clear and coherent manner. In this way, the narrative structure of the story will make sense in relation to the formal content. In order to support students' learning through evaluation descriptive rubrics could help to get a general idea of the digital storytelling and, thus, more accurate understanding of the complex, multidimensional digital story production process.

To summarize, Digital Storytelling (DST) is a very powerful and effective learning and teaching method that:

- Supports students' learning twenty-first-skill, especially collaboration, communication, creativity, critical thinking, ICT and multi-literacy skills which are extremely important in everyday life.
- Increases students' motivation, engagement, and agency in learning, and it builds confidence in students. The confidence building and success feeling are extremely important in student's optimism in future learning. Failure is also a great learning opportunity. It is the opportunity to develop students' growth mindset and to develop students' perseveres in future learning situation and in their life situations. Learning from mistakes can develop students' encourage and mindset.
- Modifies the roles of teacher and students. The students are in the center of the learning process and have more agency in their activities. They are knowledge creators, and they are responsible for their own learning and competences building. Teachers are facilitators, coaches, and act to scaffold learning.
- Impacts assessment in different ways: for encouragement and further development with constructive feedback and student self-assessment, peer assessment, and teacher assessment. The assessment is for learning, as learning and of the learning with different assessment methods.
- Enables schools to become learning communities. Principals, teachers, students, parents, friends, companies, societies are all in this learning community to support students' learning and competences development.
- Creates some challenges in using the methods. But these are not obstacles, As they can be turned to opportunities to achieve great learning outcomes with time and hard work.

The ultimate goal is to create a meaningful and joyful learning community at school where the students not only learn subject knowledge, but, even more importantly, develop the skills and competences necessary for their everyday life and their future work. DST is an effective student-centered pedagogical method which can develop students' twenty-first-century skills, agency with increased engagement. It can also be combined with other learning methods to achieve desired learning outcomes.

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Chapter 7
Wearable Technology

Miao Rong and Qu Ximei

7.1 Introduction

In recent years, with the development of mobile Internet and hardware technology, the function of wearable devices has been improved. It becomes more convenient, easier to interact, and it has better real-time performance. Wearable systems range from micro sensors seamlessly integrated in textiles through consumer electronics embedded in fashionable clothes and computerized watches to belt worn PCs with a head-mounted display (Lukowicz, Kirstein, & Tröster, 2004). They have been used wider in many fields, such as medical treatment, fire protection, military, disabled aid, entertainment, design, etc. Wearable devices also lead to the expectation that people will apply them into teaching and learning with their unique advantages.

However, the security problems in physical activities have become one of the main factors that restrict the policy of physical education in primary and secondary schools in China (Sun, 2011). Using of wearable device may be a solution. In this paper, we will talk more about wearable devices in education.

7.2 Literature Review

7.2.1 Definition

The terms "wearable technology", "wearable devices", and "wearables" all refer to electronic technologies or devices that are incorporated into items of clothing and accessories which can comfortably be worn on the body. These wearable devices can

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perform many of the same computing tasks as mobile phones and laptop computers; however, in some cases, wearable technology can outperform these hand-held devices entirely. Wearable technology tends to be more sophisticated than hand-held technology on the market today because it can provide sensory and scanning features not typically seen in mobile and laptop devices, such as biofeedback and tracking of physiological function (Tehrani & Michael, 2014).

In the *Horizon Report* of 2016 K-12 Edition, wearable technology refers to smart devices that can be worn by users, taking the form of an accessory such as jewelry or eyewear. Smart textiles also allow items of clothing such as shoes or jackets to interact with other devices. The wearable format enables the convenient integration of tools into user's everyday lives, allowing seamless tracking of personal data such as sleep, movement, location, and social media interactions (Adams Becker, Freeman, Giesinger Hall, Cummins, & Yuhnke, 2016).

Described as embeddable technology that is implanted underneath the skin, this category gives a whole new meaning to the term "wearable". An electronic engineer, for example, has designed a GPS-enabled shoulder implant called Southpaw that will prevent people from getting lost during outdoor expeditions. Another engineer has pioneered magnets that can be embedded into users' ears allowing them to listen to audio at any time (Johnson, Adams Becker, Estrada, & Freeman, 2014).

Compared with the traditional electronic equipment, wearable devices have the advantages of convenient to carry and good interact, etc., which can be used as information communication tools, seamlessly existing in people's lives, without distracting the user's life and work attention. Users can sense the environment and control the device anytime, anywhere.

When dealing with the daily affairs, Google glasses can provide users with relevant information. Users can get involved in the Internet with voice commands to reply e-mails and to do much other work. The glasses can also provide users with relevant warning information. For example, if the train that users take to campus is late, Google glasses can let them know and provide an alternative route.

Jawbone's UP wristband connects with apps that display information about how many steps the wearer has taken, heart rate, sleeping, and other health-related information, along with providing tailored recommendations for exercise and nutrition.

In this chapter, we do not distinguish between "wearable technology" and "wearable devices". Although the former emphasizes the technology, and the latter emphasizes the devices, but the wearable device uses wearable technology. Moreover, now we often use wearables to refer to "wearable devices" or wearable technology.

According to the above definition, we believe that wearable devices are smart devices (such as jewelry, glasses and watches, and other accessories) that can be worn or embedded in the human body. These devices can integrate multimedia, wireless communications, flexible screen, GPS, micro-sensing, virtual reality, biometric, and other cutting-edge technology, while they will be related to the human body to collect, process, share information, and provide feedback anytime, anywhere by the large data platform, intelligent cloud, and mobile Internet.

7.3 Research Progress

Wearable technology is not a new category; one of the most popular early incarnations of the wearable technology was HP's calculator watch, which was introduced in 1980s. In 2010, Nike+ Sportband was introduced as a device that can communicate with the sensor hidden in the shoes to tell people the details about running. In 2012, the major companies in international consumer electronics sector display their wearable devices at trade shows. It was in 2013, however, that the introduction of Google Project Glass that has opened the era of wearable technology.

"The wearable technology will drive innovation just like the personal computers of the 1980s and the current mobile computer tablets," said Mary Meeker, called the Internet Queen. "Some people have laughed at the wearable technology, such as Google's glasses, and it is just like that some people laugh at personal computers and internet" (Ye, 2014). Wearable devices have not been as widely accepted as today's smartphones, but in the entertainment, health care, security, and other fields, they have begun to play its unique role.

Using the "wearable device" as a keyword, we search in the Web of Science database. From the macro perspective, some studies demonstrate the design, implementation, and prospects of wearable devices. Focusing on the use of wearable equipment in a particular area, there are medical, sports, fitness, and education applications.

Nowadays, wearable devices have been used in the field of infotainment, such as Apple's Apple watch, Google's Google glass, Sony's Smart watch, etc., and they are launched by major electronics companies. These devices mainly meet the needs of information communication and people's entertainment (Wang, 2014).

The current wearable technology is also widely used in the field of security protection. Using built-in chip technology to detect and track the user's geographical location, and the data transmitted to the terminal equipment, the wearable devices can prevent the user from being lost to ensure users security outdoor. At present, the wearable devices mainly meet the needs of the elderly and children to prevent them from being lost. For example, GTX of the United States and the Aetrex shoe company jointly developed positioning shoes, which are embedded GPS chip, especially for patients with Alzheimer's disease.

Wearable technology has a very broad prospect for development in the medical health field. Today, these wearable devices such as smart bracelets, watches, and collars can help healthcare professionals detect data such as blood sugar, heart rate, and exercise status so that they can keep track of metrics and assign a health management programme to users to protect sudden changes in the body caused by sudden disease. Wearable devices will bring a revolution for the medical equipment industry (Xu, 2013). Google Glass is also thought to be a good way for trainees to easily acquire intraoperative footage for self-review (Paro, Nazareli, Gurjala, Berger, & Lee, 2015). The medical devices in the future will be more and more miniature, and be worn and even embedded within the human body.

In sports and training field, the United States company Zepp has developed wearable devices that are suitable for and can be used in the baseball, golf, and tennis. Athletes wear a lightweight motion sensor, which can capture their movements, and stream sports data to the data server (or mobile client) wirelessly. Athletes and coaches can analyze and play back the actions by looking at the corresponding data to improve their performance. Spelmezan and others have proposed a wearable system for skiing that can identify errors often made by beginners, such as uneven distribution of boots, erroneous postures, incorrect twist angles of upper body, and bending of knees. Once the error posture or action is detected, the wearable devices will provide automatic feedback to the mobile host device, the coach can remotely guide their posture and action. Alahakone and others proposed a gait research and recovery method. When people do exercise in the treadmill, wearable devices can identify the *heelstrike* and *heeloff* through the inertial sensor technology, achieving the effect of scientific gait training (Alahakone, Senanayake, & Senanayake, 2010).

There are also some studies aiming at specific people, such as the blind and the elderly. And a large part of these papers are conference papers. There are some empirical studies.

Koo and Fallon (2017) have studied what dimensions consumers prefer to track using wearable technology to achieve a healthier lifestyle and how these tracking dimensions are related, by the way of online survey. The enlightenment of the paper is that designers are encouraged to make wearable technology products that are durable, easy to care for, attractive in design, comfortable to wear and use, able to track preferred dimensions, appropriate for various consumers, unobtrusive, portable, and small. The research will guide wearable technology and fashion industry professionals in the development process of wearable technology to benefit consumers by helping them being more self-aware, empowering them to develop a healthier lifestyle, and ultimately increasing their quality of life and well-being.

Belsi, Papi, and McGregor (2016) designed a qualitative study using focus groups with patients with osteoarthritis. Patients' responses suggested a positive attitude on the impact wearable technology could have on the management of osteoarthritis. It was perceived that the use of wearable devices would benefit patients in terms of feeling in control of their condition, providing them with an awareness of their progress, empowering in terms of self-management and improving communication with their clinician. The information obtained from this study suggests that introducing wearable technology into patient-centered care could enhance patient experience in the field of osteoarthritis and beyond.

7.4 Cases

Currently on the market, the mainstream wearable devices include smart glasses with Google glasses as the market leader, smart watches such as Samsung, Sony, Pebble, as well as smart bracelet of Fitbit, Jawbone, and Nike coming out on top. There are also virtual reality helmets, such as Oculus Rift, Project Morpheus of Sony, which are developed primarily for games that can provide immersive, more innovative gaming experiences for users.

The following summary introduces some typical application cases of wearable technology.

7.4.1 Applications in K-12 PE Classes

Wearable technology can be applied in K-12 physical education classes and help students to establish healthy habits and help teachers adjust exercise intensity and density according to the information such as heart rate displayed on apps.

The following case comes from the seventh primary school of Zhaoqing City, Guangdong Province, and the teacher is Zhao. This class is called "durable run—campus orienteering" In the physical education class.

This course takes full advantage of the full color LED display, tablet computer, smart bracelet, orienteering marking device, and other equipment. Tablet computer, smart bracelet, and orienteering marking device can help collect students' data and upload them to the teacher side in real time, and then do statistical analysis. Then students' information can be displayed through the stage LED. Students can see their own real-time movement, and teachers at any time can get to know the movement of students and grasp the situation.

The order of class contents is: classroom routine → classroom introduction (the method of Flipped Classroom) → jogging + game, warm up → campus orienteering exercise.

The teacher uses a variety of wearable devices, such as smart wristbands, orienteering marking device, in order to achieve the training requirements for students in this class:

1. *Campus orienteering exercise*.
   - According to the problems of preview and courses' key and difficult points, the teacher explains the professional actions and precautions of orienteering. Then, the teacher sends the first map to the tablets of each student through Network disk.
   - Students plan the personalized map that owned their group on the paper maps, and upload the pictures they take to the tablets.
   - Students start the orienteering exercise under the two maps. Students test the physical data as soon as finishing the orienteering.
   - After finishing the test, showing the students' exercise load and trajectory in some parts of groups.
2. *Rules of campus orienteering*.
   - Getting four-student crews (each group has two tablets, two sports bracelets, two orienteering machines).

- Students must have two different routes of campus orienteering race according to the two maps offered by tablets.
- The personalized maps that students planned by themselves can't be the same as the routes that teachers hand out.
- Each group must record the sports time through the orienteering machine and routes by scanning QR codes.
- Students must then complete the corresponding exercise once they arrive at every site.

In this lesson, wearable devices greatly help teachers and students understand students' changes in heart rate, as well as the moving trajectory in the process. It plays a great help for the teacher's class reflection, adjustment of physical exercise. At present, the school is still communicating with the relevant enterprises, expecting enterprises to develop wearable devices and supporting platform more suitable for physical education class, to ensure that the wearable devices can provide in-time feedback about the students' data about heart rate, exercise load. What is more, the wearable devices can make real-time statistics, analysis and provide better feedback. The devices that are currently used are not perfect for these purposes.

7.5 Oculus Rift—A Virtual Reality Headset

We usually think that three main sources of power to promote the rise of the Internet is three Gs: the Game, the Gamble, and the Girl. Even now, three Gs is also the traffic sources and benefit sources of many Internet giants, largely because they represent a standard for both basic and long-term human impulse. Historically, games also change with the transition of platforms.

Oculus Rift, designed for electronic games at first, can provide virtual reality experience through goggles. YouVisit has adapted over 1000 virtual college tours so they can be viewed on *Oculus Rift* headsets. In 2014, Stony Brook University in New York and University of New Haven in Connecticut, for example, planned to implement this wearable technology into their marketing efforts. Virtual tours would allow students to go into campus spaces not typically open to visitors. From 2011 to 2014, the YouVisit tour of Yale has been viewed more than 240,000 times, with an average of nearly 10 min spent per visit (Waters, 2014). The *Oculus Rift* headset is also enabling students to explore potentially dangerous situations from the safety of the classroom. One virtual education expert has created a virtual construction worksite where engineering students can identify unsafe areas without exposure to harm. Healthcare research and training continues to advance the potential of wearable technology, as well. The Medical Virtual Reality group at the University of Southern California has developed simulations for wearable technology use for clinical purposes (Abrosimova, 2014). One of their projects focuses on medical training under simulated battlefield conditions.

Oculus Rift is also the Newest Learning Tool. A company called Chaotic Moon has combined the *Oculus Rift* headset and the Leap Motion 3D gesture controller, creating an immersive way that students can learn about atoms and molecules by looking at the periodic table of elements in 3-D and manipulating hydrogen and oxygen atoms. We usually think that people retain 10% of what they read, 50% of what they hear, and 90% of what they do. The company wants to build something that is not e-learning, but more like i-learning—immersive learning. Out of education, the platform could be useful in other sectors such as gaming or oil and gas extraction (Ariel Schwartz, 2014).

7.6 Cellphone-Charging Shirt

Researchers at the University of South Carolina converted the fibres of a t-shirt into activated carbon, turning into a wearable hybrid super-capacitator that can charge portable electronic devices. The inventors claim that the process they used on the t-shirt is less expensive, and greener, in comparison to conventional methods of creating electric storage devices.

7.7 Discussion and Conclusion

The development of wearable technology has just started. In the future, wearable products will grow at a faster rate. According to Tractica's forecast, Apple Watch in the next few years will continue to maintain the leader position in the wearable field, wearable products will focus on the field of health care; and, mobile phones will become a big control platform.

In 2013, the National Development and Reform Commission of China issued a notice supporting the development and industrialization of wearable devices, which can provide a good support in policy. From the marketing point of view, on the one hand, with the popularity of the Internet and the improvement of consumer power, consumers' buying willingness and purchasing power are increasing. On the other hand, with the growing population aging and the improvement of education, wearable technology has been expected to gradually expand from simple exercise to health care, safe positioning and entertainment experience and other aspects. These are the basis for the development of wearable devices, but at the same time, its development is also facing a lot of problems and challenges, there exist the problems of battery and relying on mobile phone in smart watches.

As we all know, Apple has popularized existing technologies for four times: with the Macintosh computer in 1984, the iPod in 2001, the iPhone in 2007, and the iPad in 2010. Recently, the faithful have prayed that Apple will pull it off again with its smart watch. The smart watch can display many of the apps that are popular on smartphones, without hassle of having to pull out a phone. So far, however, the category has remained a niche plaything for geeks and athletes. The smart watches in other firms have the same situation, such as Moto 360, Motorola's smart watches most can only make calls or perform other functions if an accompanying phone is nearby.

What's more, Apple's smart phone's battery lasts for 18 h before it needs more juice from a magnetic charger. The Apple Watch also needs to be close to an iPhone in order to function, which detracts from its usefulness.

At present, wearable devices on the market cannot have a stable consumer group. According to statistics, taking smart bracelet for an example, 42% of users no longer use the product, and nearly half of the users quit in a month, and 90% of users quit in 3 months. Most of the using habits are still formatting, and the user's dependence on the product is still weak. We think that excellent interactive design is likely to promoting the user to take the initiative to adapt to new forms of interaction and products, promoting the user to pay for the better interactive experience, while enhancing the irreplaceability of the product, which is conducive to helping to form a stable consumer group.

Meanwhile, wearable devices have so far lacked the elegant design. Even the fashion models who were hired to strut around demonstrating Google Glass struggled to make it look stylish. Apple has hired fashion-conscious executives from luxury brands like Burberry and YSL to make its watch attractive, but it is not yet obvious that it has cracked the cool code.

Maybe, for smart watches and other wearable devices, to become mainstream products will take some time. We think, maybe in some day, the advances in technology will help to solve the problem of battery and the relying on being close to an iPhone.

Nevertheless, the heat of wearable technology is still continuing. We think that the next few trends are (especially about education):

1. Application in education is developing well.

Students in Minnesota's Westonka School Distinct use the Heart Zones System, a tracker that measures their heart rate, speed, distance, and more. The distinct adopted the system to combat a drop in PE enrolment and promote fitness; educators have found that wearable devices help students develop motivation and have increased engagement (Becca Neuger, 2015).

Schools are also introducing wearable devices into physical education classes to personalize the curriculum through real-time feedback and grades based on individual skill mastery.

In China, we have consulted the school teachers in primary and secondary schools, and they think that real-time feedback in the wearable devices is very important. There are already many products that can be used to analyze the heart rate, movement trajectory, and sports load of the students after PE class, but this cannot help the teachers in the classroom to adjust the exercise intensity in time. If there are suitable wearable devices with a matching qualified system for PE classes, which can provide timely feedback of information about sports load, heart rate and so on, they will be greatly welcomed.

Except for application in physical education classes, another compelling use of wearable technology is their potential to enhance field trips and fieldwork. For instance, wearable cameras such as the Kickstarter-funded, GPS-enabled Memoto can instantly capture hundreds of photographs of data about a user's surroundings on a class trip to a museum or an offsite geology dig that can be later accessed via email or other online application (Chayka, 2012). The Contour Video Camera is another such device, currently favored by extreme athletes, that records and streams HD video. There is an increasing demand from users for all of their special moments to be seamlessly captured, but it is becoming less desirable to have to carry cumbersome devices. As technologies are continuously designed to be smaller and more mobile, wearable devices are a natural progression in the revolution of technology.

What's more, wearable devices can help students get rid of danger. When students are working in the lab, smart jewelry, clip-on earrings, or other accessories can be used to alert the dangerous situation. So far, these types of devices are mostly being developed in university labs, including "ExposureTrack"—designed at Arizona State University in collaboration with inXol that alerts people of working conditions that could potentially endanger their health (Kullman, 2013). One virtual education expert has created a virtual construction worksite where engineering students can identify unsafe areas without exposure to harm by *Oculus Rift*. Healthcare research and training continues to advance the potential of wearable technology, as well. The Medical Virtual Reality group at the University of Southern California has developed simulations for wearable technology use for clinical purpose (Abrosimova, 2014). One of their projects focuses on medical training under simulated battlefield conditions.

2. Operating system of wearables is recently concerned.

Google Glass has limited success, and Google is now focusing on providing the operating system of choice for smart watches. In wearables, it is likely that companies will make a fortune from the operating system than from selling the hardware. Many developers will wait and see which operating system becomes dominant before invest money, time and effort in wearables. Apple and Google are going head-to-head to develop the operating system, which will unite different areas of people's lives, from their watches and phones to their cars and home appliances.

Thanks largely to the smartphone boom, chips and sensors have become cheaper and smaller. This has helped wearables move "from 'Star-Trek'-like dream to reality". But it still some years before their full potential starts to be realized.

3. Less, not more.

As mentioned earlier, the smart watches must be close to the smartphones, and many features are the same with the phone app. However, maybe someday wearable technology will provide us with a "persistent" digital identity, melding the functions of house key, credit card, and a driving license in one small gadget worn on the wrist or neck, which is a little like a wristband (called a MagicBand) to get on rides, pay for food and enter hotel rooms in the Disney World theme park in Orlando.

Wearable devices hold the potential to transform some industries. Clinical trials could become cheaper and more accurate if drug makers give wearable monitors to the patients taking part. Hospitals and doctors' surgeries could use such monitors to reduce the need for home visits. Insurance firms could enter a new age in which they reduce risk as well as provide cover for it. One American health insurer is already handing out health-monitoring bands to customers, promising lower premiums for those who exercise more. Banks could reward customers who use the identity-verifying features of wearables, to cut the risk of card fraud. In PE classes, wearable technology can also help students and teachers adjust exercise intensity.

In short, wearable devices can not only help us better understand our own body, but also help us better explore the outside world, and even the universe. It is difficult, but the opportunities are boundless.

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Chapter 8
Game-Based Learning in Future School

Junjie Shang, Sijie Ma, Ruonan Hu, Leisi Pei and Lu Zhang

8.1 Introduction

Game-based learning is getting increasingly popular worldwide in recent years. According to the *Horizon Report* from 2004 to 2016 released by The New Media Consortium (Johnson et al., 2011), "game-based learning" and "educational game" are put forward as technologies that would gain widespread use in the following two or three years (2014, 2013, 2012, 2011, 2007, 2006, 2005). Reports on youth consumption of digital games are compelling, with studies such as the Pew Internet & American Life Project indicating that 99% of boys and 94% of girls play digital games. And the time youth spend on playing digital games ranges from approximately seven to ten hours per week, with more recent estimates putting this number even higher (Plass, Homer, & Kinzer, 2015). With the prevalence of game playing among children, the potential of using digital games to facilitate learning has been suggested by many researchers and educators (Li, & Tsai, 2013). Students may learn knowledge, skills, behaviors, and attitudes from these games. As people have begun to recognize the value of games, it is gradually accepted that games can not only be entertaining, but also be used for learning. Educators and researchers have reconsidered the relationship of education and entertainment. And that is why the word "Edutainment" was coined.

Game-based learning and "twenty-first-century skills" have gained much attention from researchers and practitioners. Given numerous studies that support the positive effects of games on learning, a growing number of researchers are committed to developing educational games to promote students' twenty-first-century skills development in schools (Qian, & Clark, 2016). These skills, such as critical thinking and problem-solving, effective communication, collaboration and team building, creativity and innovation, are all important for student future success. Some of the

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skills are also emphasized in the Core Literacy System of Chinese Students' Development, which was announced to public in the autumn of 2016. Game designing and playing require people to be familiar with media and technology, and it also requires people to be creative and critical thinkers, so it has great potential to facilitate students' twenty-first-century skill development (Qian, & Clark, 2016). In order to prepare students better for a future full of potentials, schools need to integrate new technology and to promote a new way of learning.

8.2 Literature Review

8.2.1 What Is Game-Based Learning?

The terms gamification, game-based learning, and educational game are sometimes used interchangeably, while some differences exist among them. Digital game-based learning refers to the usage of the entertaining power of digital games to serve an educational purpose (Prensky, 2001). As Sawyer & Rejeski (2002) argued, digital game-based learning "needn't be actual games" but can benefit from game ideas. Gamification is the use of game design elements in nongame contexts (Deterding, Dixon, Khaled, & Nacke, 2013). Educational games are games explicitly designed for educational purposes, or which contain incidental or secondary educational value. Generally, game-based learning is designed to balance subject matter with gameplay and the ability of the player to retain and apply subject matter to the real world (Team, Editorial, 2017). As a result, it contains gamification in education, educational games, and digital game-based learning.

During the 1950s, game-based learning was applied in "war game" and business school as simulated environments (Magney, 1990). During the game, groups of participants sat in laboratory role-played the national elites under the various crisis situations, or students made decisions on selling price and budget costs in a simulated environment. Gradually, the importance of game-based learning has increasingly been recognized. Prensky (2001) argued in his book, *Digital Game-Based Learning*, that computer games are effective learning tools because they sustain interest and attention in settings where people are normally bored. Similarly, Gee (2003) argued that, schools, workplaces, families, and academic researchers have a lot to learn about learning from good video games and can use games and game technologies to enhance learning. Prensky (2006) later proposed the idea with evidence to back his claim—"the true secret of why kids spend so much time on games is that they're learning things." Gamification was put forward about 2011, which represents progress of digital game-based learning in some degree. Kapp (2012) mainly stated the gamification of learning and instruction requires matching instructional content with game mechanics.

8.2.2 Why Does Game-Based Learning Work?

Some meta-analyses have synthesized plenty of research, having proven the effectiveness of digital game-based learning (Clark, Tanner-Smith & Killingsworth, 2015; Backlund & Hendrix, 2013). Hainey, Connolly, Boyle, Wilson, and Razak (2016) examined 105 empirical papers from 2000 to the first half of 2013 associated with the application of game-based learning in primary education and 45 of them were considered to be high-quality empirical studies. The learning outcomes and impact categories identified were knowledge acquisition and content understanding, affective and motivational outcomes, perceptual and cognitive impacts, and behavioral change. The greatest quantity of papers (29) were found in the knowledge acquisition and content understanding category. Six papers were found in the affective and motivational category, six were found in the perceptual and cognitive category and four were found in the behavioral change category.

A meta-analysis on digital games and learning for K-16 students (Clark, Tanner-Smith, & Killingsworth, 2016) concluded that affordances of games for learning as well as the key role of design should be highlighted. The researchers synthesized comparisons of game versus nongame conditions (i.e., media comparisons) and comparisons of augmented games versus standard game designs (i.e., value-added comparisons), then concluded that digital games significantly enhanced students learning relative to nongame conditions and that effects varied across various game mechanics characteristics, visual, and narrative characteristics.

Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2014) conducted a meta-analysis to examine overall effect as well as the impact of selected instructional design principles in the context of virtual reality technology-based instruction in K-12 or higher education settings. Key findings included that: games show higher learning gains than simulations and virtual worlds. For simulation studies, elaborate explanation type feedback is more suitable for declarative tasks whereas knowledge of correct response is more appropriate for procedural tasks. Students' performance is enhanced when they conduct the game play individually than in a group.

Thinking about reliability and validity of certain methods on assessing the effectiveness of game-based learning, due to a large heterogeneity in research methods exist. All, Castellar, and Van Looy (2016) conducted semi-structured interviews with experts in psychology and pedagogy in order to define preferred methods for conducting effectiveness studies. The proposed improvements relate to implementation of the interventions in both the experimental and control group, determining which elements are preferably omitted during the intervention (such as guidance by the instructor, extra elements that consist of substantive information) and which elements would be allowed (e.g., procedural help, training session). Also, variables on which similarity between experimental and control condition should be attained were determined (e.g., time exposed to intervention, instructor, day of the week). With regard to the methods of dimension, proposed improvements relate to assignment of participants to conditions (e.g., variables to take into account when using blocked randomized design), general design (e.g., necessity of a pre-test and control group) test development (e.g., develop and pilot parallel tests), and testing moments (e.g., follow up after minimum 2 weeks).

8.2.3 What Can Be Achieved from Game-Based Learning?

Hamari et al. (2016) investigated the impact of engagement, flow, and immersion on learning in game-based learning environments. The results showed that engagement in the game has a clear positive effect on learning, but there was not a significant effect between immersion in the game and learning. Challenge of the game had a positive effect on learning both directly and via the increased engagement. Being skilled in the game did not affect learning directly but by increasing engagement in the game. Both the challenge of the game and being skilled in the game had a positive effect on both being engaged and immersed in the game.

Game-based learning may benefit students as well as teachers. Soflano, Connolly, and Hainey (2015) studied 120 Higher Education students learning the database language SQL (Structured Query Language). A game with three game modes has been developed: (1) non-adaptive mode; (2) a mode that customizes the game according to the student's learning style identified by using a learning style questionnaire; and (3) a mode that has an in-game adaptive system that dynamically and continuously adapts its content according to the student's interactions in the game. The results showed that, regardless of mode, the game produced better learning outcomes than those who learned from a textbook while adaptive game-based learning was better in terms of allowing learners to complete the tasks faster than the other two game versions. Likewise and indicated that well-designed educational computer games might have great potential for improving the learning achievements of students. For teachers, games should be viewed as an opportunity to teacher learning and empowerment, giving teachers a sense of ownership of game-based teaching and learning (Molin, 2017).

8.2.4 How to Implement Game-Based Learning?

A model for describing the requirements for digital interactive games for use in educational contexts is proposed as a Game-based Learning model. Elements of "gameness" are divided into: interface model (look and feel); underlying model (degree to which uses a model, the game engine); interactivity and narrative (goal of story and of playing) (Smith & Mann, 2002). For the design of history courseware, a Game-based Learning model proposed include pedagogy design and digital games design to improve student engagement. Pedagogy design includes learning goal setting, curriculum needs, and educational psychology, etc. Digital games of the model include game story background, rules, challenge, enjoyment, and so forth (Mz & Sy, 2008).

8.2.5 How to Teach and Learn in Game-Based Learning?

According to an online survey involving 1668 Finnish primary, lower secondary, and upper secondary school teachers, openness toward ICT (Information Communication Technology), supportive organizational ICT culture, ICT self-efficacy, and ICT compatibility with teaching positively influenced the actual use of game-based learning technologies (Hamari & Nousiainen, 2015). So, teachers firstly should have an open mind and self-efficacy toward ICT. Results from the research on using an interpretive approach to code 35 articles indicate the teacher's role was pedagogically active in various game-based learning processes: in planning, in orientation during the gaming or after the game-play sessions (Kangas et al., 2017a, b). Based on Mishra and Koehler's (2006) TPACK, Hsu, Liang, Chai, and Tsai et al. (2013) proposed a framework of Technological Pedagogical Content Knowledge-Games (TPACK-G), which includes game knowledge (GK), game pedagogical knowledge (GPK), game content knowledge (GCK), and game pedagogical content knowledge (GPCK).

Integrating appropriate learning strategies into game-based learning can better enhance the learning performance. Meta-cognitive strategies, such as thinking aloud and modeling have been proved to be effective ways to increase students' performance both in learning and gaming by keeping them involved (Kim et al., 2008). Feedback models have been proved to affect learning behavior in game-based learning, concluded from a study on digital game-based learning approach integrating mastery learning theory and different feedback models (Yang, 2017). The study developed a mastery theory based digital game and then compare the differences in the learning behavior of students using the two feedback models. The results show that, students in the Regular Feedback Group reviewed the learning material more times than those in the Corrective Feedback Group, and both feedback methods can make students achieve the same learning performance as in the conventional learning method with a teacher involved.

8.2.6 How to Make Assessment in Game-Based Learning?

In order to determine whether game-based learning work best, validated measures of learning outcomes and the associated assessment methods are needed. Heuristics evaluation strategy is proposed to specifically evaluate mobile game-based learning, which is consisted of four components: game usability, mobility, game play, and learning content (Zaibon & Shiratuddin, 2010). Assessment while learning in a game-based environment mostly focuses on the process, game-based assessment includes three parts—game scoring, like targets acquired, obstacles overcome, time for completion; external assessment, like test scores, essay, knowledge maps; embedded assessment, like click streams, log-files with not interrupting the game (Ifenthaler, Eseryel, & Ge, 2012). Moreover, Educational games could play the role as evaluation tool. Kiili and Ketamo (2017) compared the cognitive outcomes of 51 Finnish sixth graders, who completed both paper-based and game-based math tests in a randomized order. The results showed that the game-based assessment was successfully implemented and the game provided comparable data with the paper-based test approach. More importantly, the results revealed that game-based assessment decreased test anxiety and promoted engagement.

8.2.7 How to Integrate Game-Based Learning with Other Learning Methods?

Virtual interactive student-oriented learning environment (VISOLE) uses a game-based constructivist pedagogical approach. VISOLE encompasses an online interactive world model upon a set of interdisciplinary domains, and FARMTASIA is the first online game designed using the VISOLE philosophy, encompassing the subject areas of biology, government, economics, technology, production system, and natural environment. Exploratory educational study showed that the students who participated in VISOLE learning with FARMTASIA have positive perceptions and an advancement of subject-specific and interdisciplinary knowledge (Cheung et al., 2008). A study conducted with 400 eighth grade students uses inquiry-based problem-solving strategies in CRYSTAL ISLAND, a game-based learning environment. Students were asked to work on solving mystery and complete several post-study questionnaires. The result, gained from the problem-solving time, number of attempts and correctness, showed that quantity of information-gathering behaviors has a greater impact on content learning gains and information gathering is correlated with problem-solving efficiency (Sabourin, 2012). A collaborative game-based learning environment is developed by integrating a grid-based Mind tool to facilitate the students to share and organize what they have learned during the game playing process (Sung & Hwang, 2013).

8.2.8 Where Is Game-Based Learning Going?

To detect and visualize emerging trends in game-based learning, CiteSpace V was used to carry out the keyword co-appearance time zone network visualized network. The data were downloaded from the Web of Science Core Collection. In this part, unless stated otherwise, the literature is reviewed as of May 2018. Totally 2114 valid records gained between 2007 and 2018 based on a topic search "TS = ((*game OR gamif*) AND (learn* OR educat* OR teach*))".

The time zone view of keywords co-appearance network (see Fig. 8.1) reveals the development of game-based learning which can be divided into three phases: base phase (2007–2009), stable development phase (2010–2014), the development of new phase (2015–2018). In the base phase, the most popular keywords include:

education, game/computer game/video game/educational game, environment, simulation, student, design, performance, environment/interactive environment, knowledge, engagement. Education is considered as a foundation of game-based learning. As for education, curriculum and pedagogical issues have both been researched. For example, courses using game-based learning demonstrate deeper learning (Coller & Scott, 2009). Game-based learning also can be treated as teaching/learning strategy to improve achievement (Kebritchi, Hirumi, & Bai, 2010). And instructional support in game-based learning environments improved learning (Wouters & Van Oostendorp, 2013). The effectiveness of game/computer game/video game/educational game used in education is mostly researched on learning performance, cognitive achievement, metacognitive awareness, and attitudes toward learning (Ke, 2008). As for game design, constructing a game might be a better way to enhance student motivation and deep learning than playing an existing game (Vos, Van Der Meijden, & Denessen, 2011). In the stable development phase, game-based learning, motivation, serious game are the most popular keywords. Research on prompting motivation dig deeper rather than validate the effect of GBL. Although students' initial motivation was higher, they performed poorly on written assignments and participated less in class activities (DomíNguez et al., 2013). In the development of new phase, while educational games or game-based learning have been used for years, with increasing interest in using game mechanics to foster user engagement in many nongame contexts, gamification in education become a trend. Effectiveness on students and design method of gamification in education have been focused (Hew, Huang, Chu, & Chiu 2016). Generally speaking, research on game-based learning will keep developing on the basis of education and student as well as game-related issue.

A research front is defined as an emergent and transient grouping of concepts and underlying research issues (Chen, 2006). According to the top 11 keywords with strongest citation bursts detect (see Fig. 8.2). Research front in game-based learning evolves from concentrating on students and curriculum to environment and technology, then on gamification. As the new stage of game-based learning, gamification will become increasingly popular in the next few years and that means games will be merged into education in a more flexible way. In addition, with educational games become more accessible, and with the advance of new technology, game-based learning will evolve to a business-as-usual state and maybe learning through play will be a must in school.

8.2.9 Games for Expanding Learning

8.2.9.1 FoldIt

FoldIt is an online 3-D puzzle video game about protein folding, developed by the Center for Game Science, University of Washington. Its revolutionary crowdsourcing design leveraged important scientific research on protein structure prediction and it has contributed to produce significant scientific discoveries which of them have been

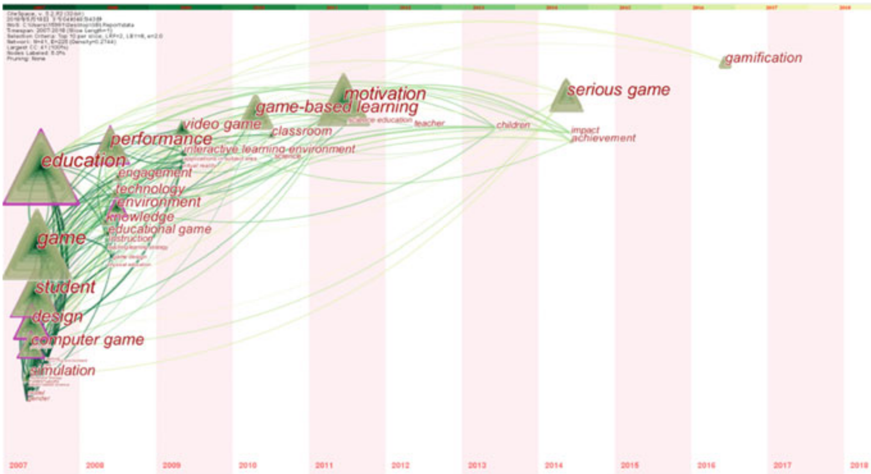
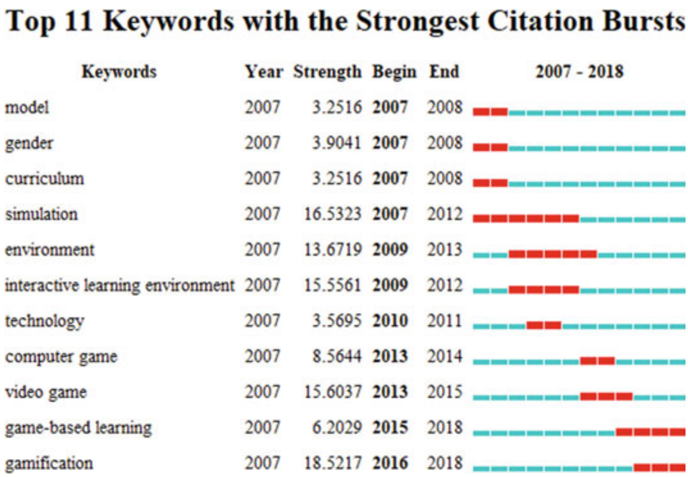


Fig. 8.1 Time zone view of keywords co-appearance network (Showing the change of research focus from 2007 to 2018. The size of triangle nodes represents frequency, the greater the node that the higher the frequency. And the purple outer ring means centrality ≥0.1. The position of the nodes is the first time when they appear. Lines between nodes represent co-occurrence.)



Top 11 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2007 - 2018
model	2007	3.2516	**2007**	2008	
gender	2007	3.9041	**2007**	2008	
curriculum	2007	3.2516	**2007**	2008	
simulation	2007	16.5323	**2007**	2012	
environment	2007	13.6719	**2009**	2013	
interactive learning environment	2007	15.5561	**2009**	2012	
technology	2007	3.5695	**2010**	2011	
computer game	2007	8.5644	**2013**	2014	
video game	2007	15.6037	**2013**	2015	
game-based learning	2007	6.2029	**2015**	2018	
gamification	2007	18.5217	**2016**	2018	

Fig. 8.2 Top 10 Keywords with the strongest citation bursts (2007–2018) (For example, model appeared from 2007 to 2008 and the citation burst is 3.2516.)

published in Nature and other leading science journals (Eiben et al., 2012). As part of so many diseases, proteins can also become part of the cure and the more we know about how proteins fold, the better new proteins we can design to combat diseases. Goals of FoldIt are to attract the attention of scientists and biotech companies and to take folding strategies that human players have come up with while playing the game. In FoldIt, more than 300,000 players modify protein structure then gain score based on how well the protein folded, which make full use of human brain's three-dimensional pattern matching and spatial reasoning ability. And Creating and joining groups facilitate solutions sharing. Accomplishments of FoldIt mainly include:

- FoldIt players can build high-quality crystal structures (Horowitz et al., 2016).
- WeFold uses the online multiplayer game FoldIt combined with collaboration and competition among research scientists and citizen scientists to address the challenge that only modest gains were made over the last decade for certain classes of prediction targets (Khoury et al., 2014).
- Crowdsourcing complex computational protein design problems can be an effective way of creatively sampling the potential sequence space for the design of active site loops that modulate enzyme activity. And Human creativity can extend down to molecular scale when given the appropriate tools (Eiben et al., 2012).
- FoldIt players outperformed the software in figuring out how 10 proteins fold into their three-dimensional configurations (Cooper et al., 2010).

8.2.9.2 MineCraft

Minecraft is a sandbox video game developed and published by the company Mojang, in which players pick and place each block at will to create a representation of real-world environment. In 2016, *Minecraft: Education Edition (Minecraft EDU)* was released to be used in classrooms around the world teaching subjects mainly on STEM (Science, Technology, Engineering, Mathematics). *Minecraft EDU* is designed to improve student engagement, collaboration, creative exploration, and tangible learning outcomes. Actually, Minecraft is already used as an educational tool for different aspects all over the world (Minecraft Teachers, 2015; Short, 2012), such as geography (Scarlett, 2015; List & Bryant, 2014), math (Bos, Wilder, Cook, & O'Donnell, 2014), spatial geometry (Förster, 2012), language and literacy (Bebbington, 2014; Garcia Martinez, 2014) social skills (Petrov, 2014), information literacy (Bebbington & Vellino, 2015), and so on. In all, as an education and scientific learning tool, Minecraft can be fabricated at will by educators to fulfill an environment which has positive effects to learning process and its features can be used for learning purposes accordingly (Ekaputra, Lim, & Eng, 2013). Minecraft can be used as an ecology learning tool for the feature of Biomes in the game, as a scientific learning tool for the feature like Redstone, and as a cultural and social learning tool for the features like breaking and placing blocks and multiplayers.

8.2.9.3 GraphoGame

GraphoGame is an early literacy game designed in cooperation with academics from universities around the world. It was developed in Finland in the interdisciplinary Agora Human Technology Center of the University of Jyväskylä in collaboration with the Niilo Mäki Institute. It is based on the scientific follow-up study of Finnish children at familial risk for dyslexia from birth to reading age which professor Heikki Lyytinen started in the early 1990s. Though GraphoGame has its origins in dyslexia interventions, it benefits all children in developing their first, most fundamental reading skills.

During the play, the main tasks include both time-restricted and untimed multiple-choice trials in which the player is to pair an audio segment (phoneme, syllable, word) with the appropriate visual representation (a letter or longer text segment). Mixed in with these reactive types of trials are the more active tasks of constructing written words from smaller components to match the spoken target words. GraphoGame algorithmically adapts to user skill levels and provides actionable learning analytics for parents and teachers. By playing the game, children learn first the basic letters and their sounds.

As an evidence-based learning game, GraphoGame is a learning environment for the acquisition of the basic reading skill for global use. Altogether, GraphoGame has supported nearly 200,000 young readers in Finland since it was launched (Richardson & Lyytinen, 2014). Researchers have conducted study in Zambia, Kenya, Tanzania, and Namibia and found GraphoGame could also be effective in supporting local children's learning (Ojane, Ronimus, & Ahonen, 2015).

8.3 Game-Based Learning Research Cases

8.3.1 Mad City Mystery

Augmented Reality (AR) games are games played in the real world with the support of digital devices (PDAs, cellphones) that create a fictional layer on top of the real-world context. Place-based augmented reality games are played in specific real-world locations (historical, geographical sites) and use handheld computers with global positioning systems to augment users' experience of space with additional data (text, numerical data, audio, video). Researchers from the University of Wisconsin-Madison have done a design-based research project to investigate the potential of place-based augmented reality gaming in environmental science with middle school students as a model of instruction suited to the literacy demands of the twenty-first century (Squire & Jan, 2007).

This study investigates the learning that occurs within game play designed around such a game, and in particular, whether a game designed around such principles can engage students in scientific thinking, specifically hypothesis formation and reasoning from evidence. The researchers designed and enacted *Mad City Mystery*, a place-based augmented reality game with three groups of students in the spring and fall of 2005. *Mad City Mystery* is a murder mystery game set in around Lake Mendota Madison, Wisconsin. Students investigate an untimely death caused by a murder, suicide, or the combination of several interacting toxic chemicals that are commonly found in the region. The game itself begins with the revelation of Ivan's mysterious death. From there, players must interview virtual characters, gather quantitative data samples, and examine government documents to piece together an explanation.

This study argues that augmented reality games on handheld computers are an exciting new pedagogical model for developing students' scientific literacy, particularly their argumentation skills. Playing augmented reality games immersed learners in a kind of scientific argumentation that is purportedly difficult to achieve and yet desired by science educators as a primary goal of science education. Such games hold potential for engaging students in meaningful scientific argumentation. Through game play, players are required to develop narrative accounts of scientific phenomena, a process that requires them to develop and argue scientific explanations. And that specific game features scaffold this thinking process, creating supports for student thinking nonexistent in most inquiry-based learning environments.

8.3.2 EduVenture(EV)

As Prensky stated in 2012, today mobile phones and tablets are an integral part of the lives of youngsters. From the perspective of education, researchers and technological educators have been looking into the potential of various mobile technologies for offering the school-age students new opportunities of constructivist learning. One of the foci is on leveraging location-based context-aware technology, particularly the Global Positioning System (GPS), to support student-centered learning and teaching activities in outside-the-classroom contexts.

Against this backdrop, the researchers from Chinese University of Hong Kong have developed EduVenture (EV), an integrated GPS-supported mobile learning system by which teachers can facilitate students conducting social inquiry learning in outdoor environments in social and humanities education (namely, Liberal Studies in Hong Kong) (Jong & Tsai, 2016).

The system consists of three integrated components: EV1-Composer; EV-eXplorer, and EV-Retriever. The EV-Composer is a cloud-based platform by which the teacher can before the fieldtrip compose an electronic resource, namely LOCALE (Location-Oriented Context-aware Learning Environment), for supporting the student to pursue the fieldtrip. The EV-eXplorer is a mobile App by which the student can access the LOCALE (designed by the teacher) via the GPS-enabled mobile tablet/phone. The current version of the EV-eXplorer runs on Apple® iOS. During the fieldtrip, the EV-eXplorer uses an avatar to denote the student's actual geographical position on the site. And the EV-Retriever is a cloud-based platform for retrieving the student's fieldtrip proceedings logged on the cloud during the fieldtrip.

The researchers held induction training (as a sort of teacher professional development) on adopting EduVenture to support outdoor social inquiry learning in Liberal Studies. After the training event, they administered questionnaire to see teachers' concerns about adopting EduVenture in practice with the Stages of Concern model, in terms of five categorical concerns–Evaluation, Information, Management, Consequence, and Refocusing. Qualitative data were gathered through observations and participant–researcher conversations. Totally 339 in-service Liberal Studies teachers participated in the induction training and 302 of their questionnaires were analyzed as others were partially completed. The study unfolded various challenges of adopting outdoor mobile learning in schooling. For example, the qualitative data showed that teachers were concerned about the accessibility of the necessary technical resources such as iPads and Wi-Fi connection in schools. They were also afraid that students would be less aware of potential dangers from the outdoor environment with the use of EduVenture. The researchers proposed interventions (from the aspects of technology, teaching implementation, and teacher professional training) with new insights into designing, developing, and appropriating their work for school education. In conclusion, this educational innovation, EduVenture, provides education practitioners (including education policy-makers, school administrators, as well as teachers) with a real instance of integrating outdoor mobile learning into formal curriculum teaching in school education, in particular, leveraging the location-based context-aware mobile technology to support social inquiry learning in social and humanities education.

8.3.3 Game-Based Learning Schools: Quest to Learn Middle School in New York and Yang Zhen Central Primary School in Beijing

8.3.3.1 Quest to Learn Middle School

Located in New York, Quest to Learn (http://www.q2l.org/about/) is a public 6–12 school with an innovative educational philosophy developed by top educators and game theorists at The Institute of Play, with funding from The MacArthur Foundation. At this school, games are defined as carefully designed, student-driven systems that are narrative-based, structured, interactive, and immersive. Classes are made up of six "Integrated Domains" which are The Way Things Work; Being, Space, and Place; Code worlds; Point of View; Wellness; and a media literacy/design course called Sports for the Mind. Quest to Learn domains are more than traditional subject-specific classes but interdisciplinary and integrate the traditional domains of math, science, history, and literature to form practice spaces for students to gain experience in different ways of knowing. Each learning context is concerned with helping students develop a game design and systems perspective of the world.

At the Quest to Learn Middle School, there are seven principles of Game-Based Learning:

- Everyone is a participant.
- Challenge.
- Learning happens by doing.
- Feedback is immediate and ongoing.
- Failure is reframed as "iteration".
- Everything is interconnected.
- It kind of feels like play.

Game-based learning takes a variety of forms. For instance, in ninth grade Biology, students spend the year as workers in a fictional biotech company, and their job is to clone dinosaurs and create stable ecosystems for them. By inhabiting the role of biotech scientists, the students learn about genetics, biology, and ecology. Educational games are at the core of Quest's curriculum. Sixth graders use Dr. Smallz, where they play the role of designers, scientists, doctors, and detectives as they explore cellular biology and the human body. And ninth graders use Story weavers, a collaborative storytelling role-playing game. These games not only engage students in the learning process, but also allow teachers to assess students in real time and provide feedback on learning experiences immediately.

8.3.3.2 Yang Zhen Central Primary School

Located in northeast Beijing, Yang Zhen Central Primary School is a vibrant school taking steps toward educational reforms as well as innovations. In the school, curriculum is structured into a "Five Plus One" system centered on "Cultivation with Vitality" and consisted of five basic literacies which are "language literacy, science literacy, virtue literacy, athleticism literacy, and aesthetic literacy." Students are provided with rich courses and practice opportunities for individualized development. From the perspective of curriculum design, learning is subject-integrated and self-regulated, which indicates the curriculum principle of "learning by doing, learning in playing, and learning from games." During their playing games, students explore and practice; during their doing activities, students perceive and reflect; and during their expressing themselves, students achieve self-worth.

Yang Zhen Central Primary School is working on building an innovative school featured in game-based learning by cooperating with researchers from Graduate School of Education Peking University. There are three projects in progress. The first project is establishing a game-based learning laboratory of innovation education (see Fig. 8.3). The second is implementing a game-based comprehensive quality assessment which integrated into students' daily learning in school. The third is launching a game-based teaching programme for teachers' professional development. All the projects are based on the current conditions and the school's education philosophy for an innovation education with game-based learning.

Fig. 8.3 Yang Zhen Central Primary School

8.4 Discussion and Conclusion

8.4.1 The Significance of Game-Based Learning

Game-based learning provides learning experience that engages students and promotes active learning. Games are viewed as providing a curriculum for the twenty-first century, one that moves beyond simply situating academic content and additionally positions learners and the spaces within which they interact in transformational ways (Barab, Pettyjohn, Gresalfi, Volk, & Solomou, 2012).

Game-based learning increases students' learning motivation as games create challenge and competition. The challenge in the game was an especially strong predictor of learning outcomes (Hamari et al., 2016). With strong intrinsic motivation, it is more likely for students to keep working hard to solve problems.

Game-based learning is fun, and students are attracted in game-based learning mainly due to this reason. However, the interactivity and design principles are at the core of the game-based learning. Not only do good educational games exemplify pedagogical principles, but some educational games can promote the achievement of learning aim as they themselves serve as roles like content, bait, and assessment (Steinkuehler, Squire, & Sawyer, 2014).

8.4.2 The Development Tendency of Game-Based Learning

8.4.2.1 Combine Game-Based Learning with Mobile Learning

As the mobile internet began to impact almost every aspect of the society, mobile technology is spreading in educational fields. Mobile learning is closely connected with game-based learning. All kinds of digital mobile devices are now being used in classroom and thousands of educational applications on the shelf have shown great potential. There are various ways to combine game-based learning with mobile learning, such as outdoor learning. Students are required to take with mobile devices, going around the city to solve problems.

8.4.2.2 Combine Game-Based Learning with Virtual Reality (VR) and Augmented Reality (AR) Technology

With the popularity of VR/AR and development of the technology, the price of VR/AR devices has decreased, which provides an opportunity for people to use them in daily life, especially in educational settings. VR/AR technology creates virtual learning situation for students to understand learning content from multiple aspects. VR/AR educational games have a broad prospect. For example, students may use VR to learn astronomy; students in vocational schools may learn some professional skills with VR. Not only is VR/AR technology a tool for presentation, observation or experience, but also a learning application for students to dig deeper and construct knowledge. Moreover, in pace with the popularization of ubiquitous technology such as GPS, WIFI and RFID, a location-aware, digital GBL environment can be easily constructed to greatly improve participation and enjoyment of learning activities.

8.4.2.3 Combine Game-Based Learning with STEM

STEM (science, technology, engineering, and math) teaching is attracting much attention in recent years. Game-based learning plays an important role in STEM teaching. For example, the Scratch platform developed by MIT has been implemented in many STEM courses, as the platform itself is a game-based learning visual programming tool. Nowadays there are more and more wearable devices and different kinds of smart devices entering the market, researchers could design educational games with these products.

8.4.2.4 Combine Game-Based Learning with Learning Sciences

Since the effectiveness of game-based learning depends on game designs, which feature a blending of established learning theories with game design elements proven successful in the entertainment game industry are most likely to lead to effective learning (Qian, & Clark, 2016), game design will be combined with results from evidence-based research in the field of cognitive science, psychology, brain science. By applying the learning principles, educational games help students to learn with scientific guidance.

8.4.2.5 Combine Game-Based Learning with Data Science

Data science employs techniques and theories from math, statistics, computer science, data mining, visualization, etc., in order to "understand and analyze actual phenomena" with data (Hayashi, 1998). Abundant Data resource in educational game provides researchers with key opportunity to gather insights on player psychology, create better learning experiences and better understand learning in game-based environments and beyond. Systematic collection and analysis of in-play behavioral data in Minecraft helped to enhance player experiences, facilitate effective administration, and unlocking the scientific potential of online societies (Müller et al., 2015).

8.4.3 Suggestions for Implementing Game-Based Learning in Future School

8.4.3.1 Establish a Game-Based Learning Environment

A learning environment is the foundation of game-based learning. As an innovative approach in education, game-based learning needs an open, shared, and immersive learning environment. In school, a game-based learning environment is where participation and collaboration are encouraged, blended learning is supported, functional zones are designed for both formal and informal learning. Establishing a game-based learning laboratory is a recommendation.

8.4.3.2 Integrate Educational Games with Curriculum and Design Game-Based Learning Curricula

From the perspective of curriculum and instruction, game-based learning needs thoughtful design. Educational games could be integrated with curriculum such as language arts, math, science, and so on. It is also possible that school design independent game-based learning curricula, setting the curriculum objectives and assessment standards accordingly.

8.4.3.3 Implement Comprehensive Evaluation with Game-Based Learning

The comprehensive evaluation includes multi-dimensional assessments of students' everyday performance. A systemic approach is needed to find out each student's strengths, potentials, and weakness so as to promote their development. Game-based learning elements such as points, badges, and leaderboard could be often used. Students' self-evaluation, peer evaluation, best works and records of different kinds of activities should be considered. The data is analyzed for individualized development of each student.

8.4.3.4 Equip Teachers with Game-Based Teaching Skills

From the perspective of teachers, there is a need to be equipped with game-based teaching skills as an essential part of continuing professional development. In order to implement a good game-based learning class, teachers should be able to scaffold performance, engage students in reflection, and draw connections between game play and curricular materials (Kim, Park & Baek, 2009; Young et al., 2012). In addition, they should know how to choose the proper games that meet learning objectives and get well prepared before class, understand students and their learning process during class, and finally reflect the game-based learning process by the end of the class.

8.5 Conclusion

In conclusion, we propose a diagram for holistic game-based learning in future schools (see Fig. 8.4). Future school will make great improvements mainly in environment, curriculum, evaluation system and teacher, as game-based learning applied in. All the teaching and learning method change are driven by evaluation change. Curriculum is the core for school, in game-based learning the curriculum will become more scientific and much happier. Learning environment is the base of game-based learning, related to the goal and way to cultivate students.

There are three layers and four parts in the pyramidal structure. Learning environment lays the foundation of game-based learning. The middle layer consists of two parts. One is integrating game-based learning with curriculum, and the other is designing school-based curriculum. These are two different approaches to game-based learning in terms of the curriculum level. At the top of the structure is the comprehensive evaluation, including multi-dimensional assessments of students' performance. As teacher training is essential to implementing game-based learn-

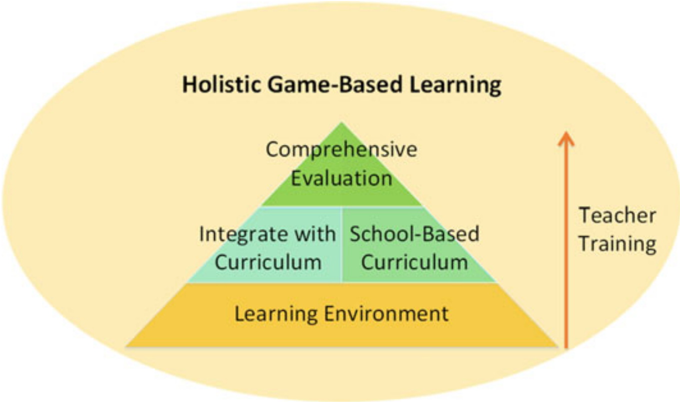


Fig. 8.4 Diagram for holistic game-based learning in future school

ing in school, it should be emphasized and aligned with game-based learning as we suggest.

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Chapter 9
Collaborative Wiki Writing Gives Language Learners Opportunities for Personalised Participatory Peer-Feedback

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9.1 Introduction

This review is for learners and teachers of modern languages internationally who are interested in using digital media and online tools such as collaborative wikis to develop students' writing skills in another language. We report current research

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literature on using collaborative wikis to develop language learners' writing skills and other relevant social and learning skills in a language they are learning (a target language), such as English, through iterative online practice. We focus in particular on how giving and taking personalised participatory peer-feedback develops learners' writing skills.

Informed by our experiences of using wikis in class and supporting online collaborative writing in English in five provinces in China, we also set out the reasons why enabling individual language learners to organise themselves into small groups, write together and give each other feedback as well as receive feedback from the teacher can be an effective means of creating an interactive and engaging environment to learn another language. The environment encompasses a number of social groups: a team for learners to write collaboratively with who are also their audience and their community of peers giving feedback; writers in other related groups; teachers, to explain how wikis work and to set up the writing activities; and readers in other online communities, if access is enabled for them.

Two terms, important for our review, are defined here:

Online collaboration is when people of equal status who are mutually and reciprocally committed to work together interact through one or more networked platforms and communication tools to achieve a shared goal. Collaborators build and sustain intersubjectivity (they are aware that they share understanding about achieving their goal), they negotiate meaning together, and if the writing task is well designed and the learners are engaged in achieving the goal together, they may experience interthinking (the process of supporting, sharing and coordinating cognition in working towards a shared goal, see Mercer, 2000) which may result in groupsense or a social 'feeling of shared endeavour' (Luckin, Baines, Cukurova, & Holmes, with Mann, 2017: 11). This definition draws on Littleton and Mercer (2010) and Wenger (1998).

Personalised participatory peer-feedback is the ongoing dialogue of responses to the shared endeavour between collaborating learners of equal status who are mutually and reciprocally committed to working together. Peer-feedback may also be given by learners from different groups on a mutual (exchange) basis, however, peer-feedback is only participatory when given by peer collaborative writers. Here 'personalised' refers to feedback that is individually generated and individually consumed but mediated through the group's collaborative product. See Jenkins, Ito & danah boyd (2016) and Spilioti (2018) for further discussion of participation among social media users.

Below we explain what wikis are, the basics of how they work, and why wikis are useful for developing learners' writing skills in a language they are learning. We review what learners learn through using wikis for collaborative writing in another language, how they feel about it, implications for time and efficiency, and some advantages of personalised participatory peer-feedback for language learners and teachers. We draw on evidence currently available, and we show examples of wikis used for writing development.

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9.2 What Is a Wiki? How Do Wikis Work?

A wiki is a digital medium and online collaborative platform that enables people to work together (Myers, 2010)—it is used as a tool for text or materials creation, collaborative writing and sharing materials and storing data, such as text files, images, audio files and video files. The wiki requires internet connectivity and a digital device (the device may be mobile, such as a phone or laptop).

The wiki was developed as an online collaborative writing platform to enable people to work together and it is now extensively used by many companies, institutions, groups and individuals. The most famous wiki is Wikipedia, the online encyclopedia, where experts contribute to entries in their own areas of expertise and each language has a separate wiki. Over time entries are updated and develop in depth of explanation and number or breadth of entries as expertise develops in the area and more people contribute (see Fig. 9.1).

Wikis are useful not just for encyclopedias but for any collaborative enterprise because the wiki affords collaborative sharing of the work of writing (see Gibson, 1979, for his theory of affordances, that objects can be perceived in terms of their possibility for action). Text on a wiki can be created, put online, and edited by group members—it is also possible to delimit who has access to editing and who has access to reading a wiki. Contributions to the text can be made anonymously, so it is not possible to view the authors' names in the main text. However the wiki's history contains a record of all the changes made to the text and the online identity of the author (see Fig. 9.2).

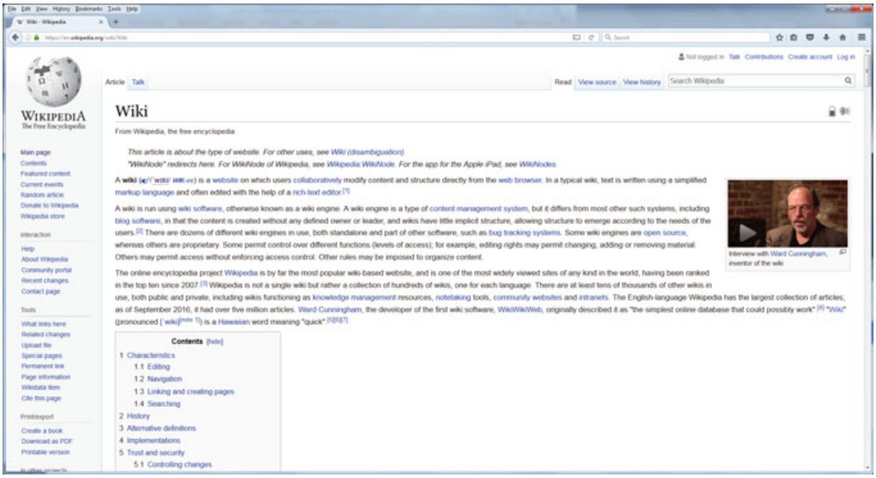

Fig. 9.1 Screenshot of the entry for the Wiki on Wikipedia, the online encyclopedia. The sidebar (left) and the menubar (above) show tools and functions. The embedded photograph is of Ward Cunningham, who developed the wiki in 1994 (Wikipedia, 2017)

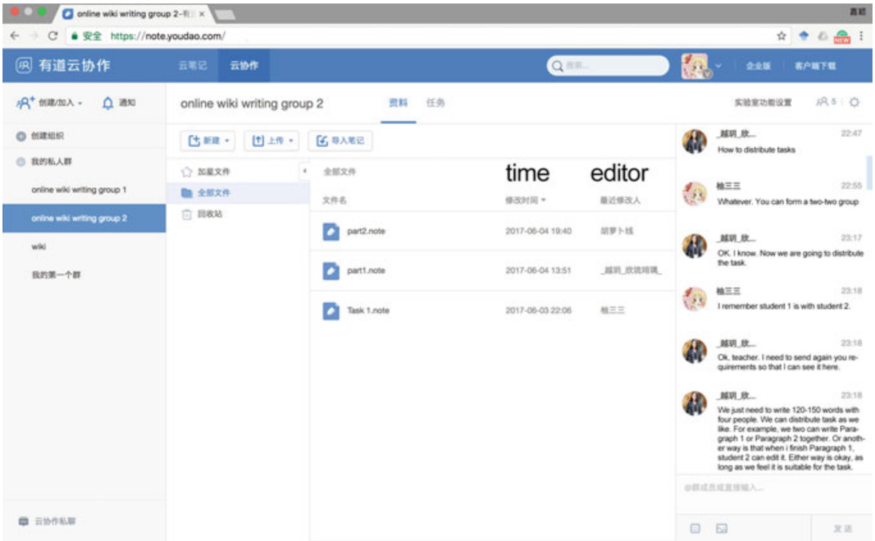

Fig. 9.2 This screenshot is an example of a collaborative writing wiki used by a group of learners at school in China to develop their English writing. Each person's contributions are uploaded separately. Note the iterations of the uploaded text in the centre, which also show its history, and on the far right, the writers' and teacher's discussion about the writing process and the text. The writers are using profile usernames in Chinese and avatars rather than their own identities to protect themselves online

The wiki enables language learners and their teachers to develop an online language-connected community for social learning because each wiki maintains a history of what each person contributes. For collaborative writing, each person contributes to the text and the shared discussion that may be produced in creating the text (see Wenger, 1998, on communities of practice). The community of learners can use online resources in and out of the classroom to collaborate and—in the process—to practise the language they are learning using all four language skills: listening, speaking, reading and writing.

9.3 How Do Wikis' Design Functions Enable Language Learners to Write Collaboratively?

Wikis were specifically designed for online collaboration. They permit multiple writers to create, edit and discuss web content (Storch, 2011) using the three wiki functions (after set-up): edit, discussion and history. The editing function enables writers to write, revise, edit, correct and proofread. The discussion function enables writers to interact and negotiate together in turn over their planning, monitoring and evaluating of their shared text and its possible developments. The history function enables writers to track back through the different contributions to the text that occurred through editing, which is useful for further correction and critical evaluation of the writing processes and enables writers to return to a previous version at any time (see Storch, 2011, for further detail).

Wikis' design functions make them very useful for language learning:

– Wikis are quick and easy to set up.
– Learners can work on the same writing activity either in the same class with each learner on a separate computer or device, or in separate locations online.
– Learners can contribute in their own time and at their own pace (Colomb & Simutis, 1996).
– Depending on the type of wiki, learners can work synchronously or asynchronously (at different times). All types of wiki enable written interaction with possibilities for negotiation of meaning and form as part of 'the reflective nature of composing' (Ware & Warschauer, 2006: 111).
– Learners are working in their own environment: educational wikis can be set up as a safe space for writing with privacy settings to exclude non-members.
– Each wiki records who contributed what and learners can easily retrieve or revert to a previous version if they wish.
– Learners can use their wiki as a collaborative knowledge store where they can post useful materials for their studies along with their views of them, in order that their writing group can have access to these materials and metadiscourses (the discussions).
– Learners can upload audio and video files to share as input for writing, which develops learners' listening and speaking skills as well as their reading and writing skills in the target language.
– Learners can discuss their work and their collaboration within the wiki, which is particularly useful for language learning because negotiating meaning through naturally occurring interaction develops language proficiency. This design function means learners can co-construct their writing at the same time as negotiating with each other in their parallel discussion of the text. Both forms of interaction can result in focus on the language of the text, discussion of the writing process and learners receiving ongoing personalised participatory peer-feedback.
– Collaborative wiki writing may result in a sharing environment as 'individual knowledge creation moves up to the level of collective knowledge innovation through mutual collaboration and enlightenment' (Jiao & Yuan, 2008: 652).

Wikis' design functions also make them useful for language teaching. For example, teachers can set up their own wiki with a list of links to their students' wikis (see Fig. 9.3). This embedding function gives teachers swift access to each group's work for formative feedforward and encouragement during the process of writing, as well as summative feedback and feedforward after their learners have finished writing. Teachers can answer their learners' questions within the wiki, which is particularly helpful in large classes where learners might hesitate to ask. Teachers can view

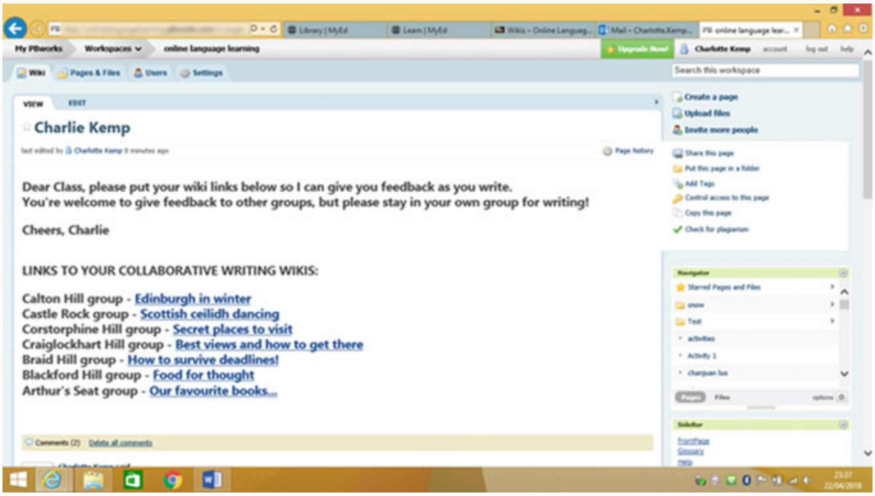

Fig. 9.3 Screenshot of a wiki used by one of the authors to access their learners' wikis to give feedback

which individuals are actively contributing to the text and which need support and encouragement. Teachers and learners can choose whether to enable other learners outside the collaborating group to read and give peer-feedback on the collaborators' work, bearing in mind the rule of mutuality—that the feedback is given on a two-way exchange basis with their own group's work. So as part of learner collaboration, the wiki affords personalised participatory peer-feedback as well as teacher monitoring and feedback.

9.4 Why Is Collaborative Wiki Writing Useful for Developing Writing Skills in Another Language?

Communication is collaborative—it requires a community of people to share meaning—so when we learn another language, we need to become part of that language community. Spoken communication is clearly collaborative, for example, in conversation both/all speakers respond to and build on each other's contributions, but writing in educational environments can also be collaborative, so that the collaboration builds a community of people using the written language. Writing does not *need* to be an individual activity such as in a class where each learner writes individually, as Ede and Lunsford (1990) point out, though it often is for two main reasons. The first reason is educational ideology—that testing is solo so learning should be too. The second reason is resourcing constraints: offline teachers need enough class time, and learners need to be together in one place to share resources such as materials and a table, and they need to be quiet enough for other teachers nearby to be able to teach and other students to learn. The reason collaborative wiki writing is useful for developing writing skills in another language is because it facilitates writing through the formation of language micro-communities where members scaffold each other's learning, and it does not share these offline constraints of time and place (though it has other constraints such as: time outside class; access to a device and connectivity; and constraints due to properties of the wiki, e.g. older types of wiki require the whole text to be uploaded at each iteration).

Collaborative wiki writing is also useful for developing writing in another language because using the shared online platform means that learners can move beyond cooperative writing to a far greater intensity of cooperation, namely, collaborative writing. Collaborative writing is distinct from cooperative writing (Stahl, 2006). In cooperative writing, people work together for the same end, for example, they divide up a text and write different parts before putting the overall text together, followed perhaps by cooperative peer editing. In collaborative writing, people share all the writing, rather than share out the writing (loc. cit.). So collaborative writing is the *process* of sharing the writing of a single text together so that it is not possible to separate the different contributions.

Collaborative writing can also be the *product*, i.e. the text, written, negotiated, shared and owned by more than one person (see Stahl, 2006). The collaborative text may be mainly written in the target language (e.g. English) with place-holders used where learners know what they want to say but do not have the language to express it. Teachers can ask for learners' parallel discussion of the text to be in the target language as well (so writers' language development is observable in both process and product), but interaction in any language that the learners know can help in constructing the text. Writers can learn through this collaborative process, and we can see evidence for this in the written product: for example, collaborative texts can be more accurate than pair and individually written texts (Dobao, 2012).

Both the process and the product of writing depend on co-writers (in this chapter, we mean collaborative writers) constructing shared cognition of the text and the writing process in the form of team-shared mental models. Establishing and maintaining this intersubjectivity requires written and/or spoken negotiation between the group members for process and product, which may lead to co-construction of understanding or interthinking (Mercer, 2000) and possibly groupsense (Luckin et al., 2017), which learners enjoy and find rewarding.

To sum up, collaborative wiki writing is useful for developing writing skills in another language because learners form a community to learn from each other and create a text together as a product while being scaffolded in the process of writing by their peers and their teacher (see Storch, 2013, on Vygotskian sociocultural approaches to writing). Writing is social communication and collaborative wiki writing is a social process, a social product and a social event, whether supportive or challenging for the learners.

Innovation arises from this kind of learning. Ideas, new methods and new language that are found to have value or application are incorporated into the practices of the group as part of their individual and group expertise, and they may be passed on to other community members. As part of their expertise, the learners may then use these ideas and new methods in learning other additional languages.

9.5 Skills Development: What Do Learners Learn?

Evidence that the process of collaborative online wiki writing in a target language improves writing in that language (e.g. English) is not surprising—writing is a language skill and learners need practice to develop. But research has found that learners using wikis for collaborative online writing can also develop a number of other skills. By skills development we mean the process of gaining and combining procedural expertise and domain-specific knowledge adaptively over time through intentional, systematic and sustained practice to capably accomplish complex activities with regard to accuracy, speed and performance. Developing these skills is dependent on the design of the tasks and activities that learners carry out in the collaborative wiki writing. Note that the process of collaborative writing integrates a number of different kinds of skills so separating them out here is for language learners' and teachers' consideration rather than because they are separate processes:

(1) **Idea creation skills**: how to think of ideas to contribute to the text; how to generate ideas for others to evaluate and synthesise with their ideas; how to synthesise ideas with others' ideas to create a new entity, such as a new concept, topic area or argument.
(2) **Writing skills in the target language (communication skills)**: how to be an effective communicator by using written language to convey meaning that is pragmatically appropriate for the audience and message, for example: how to structure discourse to put forward ideas or arguments; how to use formulaic language; how to collocate words appropriately; how to use grammar in keeping with the register and genre; how to use register appropriately for the audience; how to integrate multimedia communication such as subtitled videos with the written text; how to synthesise written and multimodal contributions from different authors over the timeframe of the writing process to make a single complete text.
(3) **Information literacy skills**: how to set up and use wikis; how to access information online; how to navigate the social network architecture of the wiki; how to use IT knowledge and understanding to create knowledge together as a group; how to contribute IT knowledge and understanding to support group members; how to write collaboratively using a wiki (as a practical skill).
(4) **Social and interpersonal skills**: how to collaborate; how to cooperate; how to give and take peer feedback on language, content, contribution, and participation; how to negotiate; how to build and maintain relationships; how to discuss with peers in an online medium; how to agree/disagree, resolve disagreements and move forward with the resulting decisions; how to support others' thinking (Luckin et al., 2017); how to support peers in the process of collaborative writ-

ing; how to share roles (collaboratively) or share out roles (cooperatively); how to have fun while working together; how to create groupsense; how to write as a team. Developing these social skills for wiki writing is a process of online and offline socialisation which relies on empathy.

(5) **Personal skills**: to take responsibility for making collaborative relationships work; to be proactive within the group; to set personal goals that support the group goals; to understand the context of learning and of writing; to be personally effective within the group; to develop responsibility for co-producing text and co-ownership of the text; to develop greater self-awareness; to develop responsibility for how the self is represented online (see Page, 2018); to self-regulate in achieving a collaborative goal; to take responsibility for personal development; to develop greater autonomy—collaborative wiki writers need to make choices about who they work with, how they work, and their division of labour (see Benson, 2011).

(6) **Academic or cognitive skills**: how to analyse and evaluate information critically and then come to a reasoned decision; how to solve problems; how to synthesise ideas, arguments and language from multiple sources critically.

(7) **Metacognitive skills**: learners' cognition (thinking) about the skills listed above may in turn help to develop their metacognitive skills, i.e. thinking about thinking (see Gombert, 1992, for a summative history of the term 'metacognition'). The interaction and negotiation involved in explaining and defending ideas develop critical thinking skills i.e. learners develop in their ability to evaluate and analyse their own and others' ideas. Metalinguistic skills (i.e. thinking about language) such as planning, monitoring and evaluation of the text, and metacognitive skills such as planning, monitoring and evaluation of the writing process or of the language learning process can also develop through collaborative writing.

To sum up, collaborative wiki writing and using wikis as a tool to develop writing skills in another language may also develop other important skills: idea creation, writing, and information literacy, as well as social and interpersonal, personal, academic or cognitive, and metacognitive skills. Developing these skills is useful at home and at school and advantageous for learners' future education or workplace (see Benson, 2011).

9.6 How Do Writers Feel About Writing Collaboratively Using a Wiki?

Learners' affective states may also be influenced by collaborative wiki writing. Co-production of text and shared decision-making may result in co-writers having a sense of achievement that they have created a text that they would not have created individually, but that they share ownership of (Storch, 2005). Learners may gain confidence in their writing (Yong, 2006), and the experience may lead to positive attitudes to writing collaboratively. Learners may become more motivated to write, and learners who enjoy the writing experience may write more in any of their languages. With regard to anxiety, learners may find online communication less stressful than face-to-face communication: learners have reported that receiving feedback online is less face-threatening than in person (Vorobel & Kim, 2017: 87).

9.7 What Are the Implications for Time and Efficiency?

Time is one of the main constraints in classroom teaching. Blending collaborative wiki writing outside class with in-class learning may benefit language learners if they spend more time on task: a much-cited meta-analysis of general online learning finds that blended learning is more effective than face-to-face learning because learners spend more time on task (Means, Toyama, Murphy, Bakia, & Jones, 2010). The study also shows that when the online element of blended learning is collaborative (or teacher-directed), it is more effective than when learners learn independently online.

For teachers, collaborative wiki writing is time-efficient because writing development requires feedback that is appropriate and specific to the learner, which can be time-consuming and effortful for the teacher—collaborative wiki writing can save time with regard to administration, the interval between students creating written work and teachers' access to it for feedback (Su & Beaumont, 2010), administering different student groups' writing, and students receiving their feedback. However, our respondents in a group study we carried out in senior high schools in China note that both teachers and learners may need some time initially to learn how to use the chosen wiki platform, and it takes learners time outside class to engage in collaborative writing, which is affected in turn by each individual's own resource constraints.

9.8 What Are the Advantages for Language Learners of Personalised Participatory Peer-Feedback Through Wiki Writing?

Receiving appropriate and useful feedback from any source is advantageous for language learners, but there are characteristics of peer-feedback through wikis from co-writers and fellow learners engaged in the same activities that are particularly useful in meeting language learners' complex needs.

Firstly, writers need an audience (Jahin, 2012). Wiki writers in a collaborative group form their own participatory audience which gives them the opportunity to receive personalised participatory peer-feedback and to find out how their co-writers respond to the developing text. The collaborative group can also find out how their fellow-students from other wiki writing groups respond to the developing or finished text, as well as their teacher. What other people think about the content and language of learners' text and how co-writers develop an understanding of how others interpret them is important for developing communication skills (Hyland & Hyland, 2006: 6).

Then, writers need ideas. Participatory peer-feedback enables learners to share and discuss their ideas through a process of negotiation (Wigglesworth & Storch, 2012) and co-construction of knowledge (see Vygotsky, 1978). Writers may also discuss their shared goals and objectives, the process of how they are going to write together, their constraints and their beliefs and attitudes about writing. Writers may discover gaps in their own individual understanding of ideas. To address these gaps, writers may refer to their co-authors and the internet for information and support.

Most importantly, language learners need language input in order to bridge the gap between what they are able to write and what they want to write in response to the rubric or assignment brief. Receiving participatory peer-feedback on language can be useful for online collaborative writers particularly when they can all draw on the huge variety of resources online. For example, learners can use online dictionaries, use the internet as a corpus, find relevant content and ideas and find out what other writers have produced on the same topic. Learners can control this online input: in offline teaching of writing the teacher may control access to input materials such as coursebooks, audio recordings and dictionaries. The process of language-data-gathering, with each learner being able to look for supporting language materials at will, in conjunction with individual and group collation and analysis of the language, develops learners' proficiency as well as their knowledge and understanding about how the language works.

Learners may also need language output (i.e. to write/speak/sign) in order to develop proficiency (Swain, 2000). Writing in a collaborative group can provide suitable conditions for learners to produce 'pushed output' (see Swain, 2000). In other words, the necessity of making the effort to be understood in negotiating meaning in the language they are learning results in learners producing language that they might not be capable of in other circumstances. This negotiation between co-writers goes far beyond finding appropriate words and being able to use the correct grammar, and into the territory of co-constructing meaning in order to co-create texts that work communicatively for a specific audience.

Next, learners need to solve linguistic problems in order to be able to write in the language they are learning—problems such as negotiating what to write, expressing their ideas and structuring them in a way that is understandable to others. By working in a collaborative wiki group, learners can scaffold each other (see Vygotsky, 1978) and give personalised participatory peer-feedback during and after writing. Here scaffolding conforms to van Lier's (2004) two key conditions—that learners try new ideas or language while being supported, and that the aim is for learners to take control and the scaffolders to cede control as the support is appropriately withdrawn. Most research on collaborative writing uses Vygotsky's concept of scaffolding as a theoretical underpinning (see Storch, 2013).

Socially, wiki writers need to be able to take on different roles and receive peer-feedback on their contributions in these roles in the process of collaborating. When writers collaborate, they may assume roles that differ from their usual roles (see Weissberg, 2006) and these roles may depend on the interacting constellation of roles assumed across the wiki writing group. For example, online a co-writer may be a group member, who takes part in discussions and is recognised by others in the group; the co-writer may be an expert, who contributes actively and guides or mentors others; the co-writer may be a sounding board who listens and comments on others' input before it is put forward in the text; the co-writer may be a critical reader who works to improve the text; and the co-writer may be a lurker, who reads material online but does not actively contribute to the group's activities. So in producing a collaboratively written text, writers may assume multiple roles or move between these roles depending on their relationships, motivations, individual and shared goals and skill sets across the timeframe of the writing. In addition, the group as a whole or subsets of writers within the group may assume a group role, e.g. the idea-creators, the editors. Personalised participatory peer-feedback is useful among collaborative wiki writers for enabling, supporting and developing each other in assuming different roles.

Furthermore, taking up the role of teaching or giving feedback may develop learners' skills—known as the 'protégé effect' (Okita & Schwartz, 2013). Teaching or giving feedback may benefit the giver as well as the receiver because people learn more by teaching it to others than if they just learn it for themselves. Evidence for the 'protégé effect' is lacking in language learning research, but language teachers often point out 'if you want to learn something, teach it'. Giving peer-feedback requires the giver to understand the language/text and ideas and how writers are meeting the goals of the activity so the giver can respond meaningfully with suggestions, amendments and support. In other words, developing learners' ability to give feedback may not only be useful for their peers, but also for learners' own language development.

Observing feedback may also benefit co-writers. Observers who are part of the collaborative group but not part of a specific contribution and feedback interaction can learn from others' feedback on others' errors and be part of a feedback-rich community. Observing a variety of different feedback from different points of view can be very valuable in developing group writing and individual proficiency.

For all co-writers, the usefulness of personalised participatory peer-feedback is still reliant on the teacher being available and alert to ensure that comments are appropriate and helpful for the writers (Hyland & Hyland, 2006), and it should be noted that students value their teachers' feedback more than their fellow-writers (Ferris, 2006).

To sum up, the process of giving participatory peer-feedback through wikis can meet many complex needs in language learners. A collaborative environment rich with supportive, appropriate and useful feedback is beneficial for all writers and may speed the development of writing skills with the same amount of time and effort while at the same time developing cognitive and feedback skills such as monitoring and evaluation. Peer-feedback is an important part of teamwork in a distributed environment and an important skill to develop for students' education as well as for their future working lives.

9.9 What Are the Advantages for Language Teachers of Their Learners Using Wikis for Personalised Participatory Peer-Feedback?

The clearest advantages for language teachers are the possible development in their learners of the skills sets (see above): idea creation, writing in the target language, information literacy, social and interpersonal, personal, cognitive or academic and metacognitive skills, as well as positive affect (e.g. motivation). As learners take on some of the roles that may previously have been taken only by the teacher, and as observers learn from others' feedback, it is possible that using wikis may ease teachers' workload (Lee, 2011) depending on the writing activities or tasks, how the wikis are set up, and how learners respond to them.

A further advantage is that because the wiki is both a digital medium and a tool for writing, it can be used to teach a language through any teaching methodology or none. These affordances enable teachers to move beyond specific language teaching methods to a post-methods approach, i.e. to focus on learner needs, and to follow Kumaravadivelu's (2003: 36) proposal for the three pedagogic parameters of 'particularity, practicality and possibility'.

Particularity refers to language teachers' sensitive adaptation and response to their own particular learners in their learning context, social environment and location. Using a wiki enables the teacher to see and comment on their students' writing at any point in the online writing process, to choose the most appropriate time to give feedback, or to monitor and hold back from comment. For example, teachers may decide to comment on and contribute to their learners' negotiations about their writing and their co-writers' contributions, or they may decide to give feedback after co-writers and peers have given feedback and the texts have been revised. (Teachers may also prompt learners to give each other peer-feedback in order to enrich particularity). Teachers are able to gain an understanding of their own learners' needs and development through seeing their *process* of writing (Yong, 2006) and are able to track through learners' development in a single overview of the wiki.

Practicality refers to language teachers theorising from their practice and practising what they theorise from teaching their own learners in their own social and institutional context. Language teachers can adapt their practice of how they use wikis to give personalised participatory peer-feedback to meet their own learners' needs and goals. Teachers can then use their experience of this practice to inform their ongoing theories of how to use wikis for future collaborative writing activities and how they fit with individual writing activities. This post-methods reflexivity gives teachers a robust teaching advantage in meeting learner needs compared to using other teaching methods and approaches.

Possibility refers to learners' search for possible social identities and for possible transformation of social inequalities. Using a wiki for collaborative writing can empower learners as it is learner-centred, and it can empower language teachers to provide their learners with the possibility of exploring their self-identities and assuming different social roles (see above) while receiving peer-feedback on their interactions in these roles. This exploration is important for developing each individual's social, affective and cognitive potential.

To sum up, using wikis for personalised participatory peer-feedback gives language teachers some strong theoretical and practical advantages and enables them to use a post-methods approach in applying 'particularity, practicality and possibility' to their writing activities (Kumaravadivelu, 2003: 36). Individually, these advantages support the teacher and the learners: collectively, the combination and interaction of these advantages in using wikis for collaborative writing may be very powerful.

9.10 Conclusion

Developing skills in online collaboration is important because advances in technology—in contexts where people have access to devices and connectivity—are leading to changes in society and changes in education. Enabling people to adapt responsively to a changing world over their lifespan and to thrive is one of the many goals of education. As educators, we cannot teach the technology of the future, but we can aim to support and enable our students to develop a mindset that reaches out to new technological developments and works out ways of using them in ways that will benefit their lives.

Collaboration is central to this venture (OECD, 2017). To learn to collaborate effectively, people need to develop a skillset that includes practical social skills gained through the experience of working together to achieve a shared goal. These collaborative skills may not be testable in individual examinations, but they are part of the skillset needed for work and life. Collaboration and groupwork are features of our working, home and social lives and how we collaborate, including our collaborative reach and effectiveness, is developing very quickly according to the affordances resulting from developments in technology. Technology is being developed to enable us to communicate with more people, in different ways, and with greater synchronicity, which will enable us to achieve more in future through social collaboration across languages and cultures than is currently possible, e.g. the latest generation of wiki affords simultaneous editing by multiple users. Collaborative wiki writing in another language is part of this enabling skillset. Using collaborative wiki writing is one small practical way of developing learners' language, idea creation and information literacy skills, together with social and interpersonal, personal, cognitive/academic and metacognitive skills through its opportunities for personalised participatory peer-feedback.

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Chapter 10
The Role of Cognition, Motivation and Well-Being in the Mathematics Learning

Pirjo Aunio, Markku Niemivirta and Mari Tervaniemi

10.1 Introduction

The effectiveness of any given educational system may be defined by its capability to prepare the students with relevant academic competencies and to support their more general well-being and motivation to learn. These educational outcomes represent the mental resources that help the student to adapt and actively act in society. Students' mathematics skills have proved to be highly predictive of students' overall academic achievement and educational dropout. Engaging motivation and well-being, in turn, are both significant educational outcomes and factors that importantly contribute to students' learning. In this chapter, we will review research on these areas, with the intent to chart the developmental nature of children's mathematics learning and how it is influenced by various cognitive and motivational factors, and what the role of students' well-being is in this interplay. Finally, we will explore how art-based means, and particularly music, could help to support learning through both facilitating cognitive functioning and enhancing motivation and engagement. Due to the contextual framework of this book, we will focus on research conducted in China and Finland.

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10.2 The Development and Individual Differences in Mathematics Learning

Developmental research suggests individual differences in mathematics skills to be evident already in preschool, and from then on, the gap between low and high performing students only seems to get larger. Low performance in mathematics seriously interferes with students' achievement in related domains (e.g., science), narrows down their educational and career opportunities, and hampers employability and even daily living (Battin-Pearson et al., 2000; Hakkarainen, Holopainen, & Savolainen 2012; Korhonen, Linnanmäki, & Aunio 2014).

Motivated by the importance of mathematics skills in later life, we reviewed Chinese and Finnish studies on individual differences in mathematics learning over the past 15 years. The development of mathematical skills has been approached from two viewpoints: (1) explaining mathematical skills development with previous mathematical skills, and (2) exploring cognitive skills as the explanatory factor.

10.3 Explaining the Development of Learning with Early Mathematics Skills

Mathematics learning begins early in life. In fact, we are born with some understanding of numerical magnitudes (Dehaene, 1997, 2011). Young children start to learn culture bound numerical skills like reciting number word sequence (one, two, three …), and along practice, learn to use number word sequence to enumerate. They also learn to make relations statements about which set has more or less (see more Aunio & Räsänen, 2015). These early skills support later mathematics learning.

The idea of a spatially oriented mental number line has widely investigated. For instance, Tzelgov, Ganor-Stern, Kallai, and Pinhas (2015) described the mental number line, not only as culturally shaped representational medium to efficiently code and to compare the meaning of natural numbers, but also as a cognitive scaffolding mechanism that helps children to utilize syntactic processes to derive the meaning of multi-digit integers, negative numbers, and fractions. In a cross-cultural study on number-line estimation (Siegler & Mu, 2008), Chinese kindergarteners' estimates were considerably more accurate than American kindergarteners' estimates.

The good number knowledge is highly important for place-value understanding (i.e., understanding the positional values and interrelationships of digits in a number). Chan, Au, and Tang (2011) showed that Chinese children aged 6–7 years can process two-digit numbers automatically early in elementary school, which suggests children to use their recognition of the decompositional structure of the Arabic numeral system. Chan, Au, and Tang (2014) suggested that Chinese children start to construct number meaning already in kindergarten. They start with the unitary multi-digit concept, then they use sequence-tens and one's concept, and subsequently reach the separate-tens and one's concept. The separate-tens and one's concept, however, is likely facilitated by the Chinese number words, with clear mapping onto the place values of the digits. Their results also showed that the children's place-value understanding in kindergarten was the single strongest predictor of their mathematics performance one semester later (see also Chan, Au, & Tang, 2013; Chan & Ho, 2010).

The development and individual differences in children's early numerical skills have been studied in Finnish (Aunio, Ee, Lim, Hautamäki, & Van Luit, 2004; Ee, Wong, & Aunio, 2006). The results by Aunio and Niemivirta (2010) demonstrated the acquisition of counting and numerical relational skills before formal schooling to be predictive of the acquisition of basic arithmetics skills and overall mathematics performance in grade one, above and beyond the effects of demographic factors (age, gender, parents' education). In a similar framework, Aunio, Heiskari, Van Luit, and Vuorio (2015) showed that differences in numerical skills among children are already visible in the beginning of the kindergarten, and the low performing group improved in skills, but did not catch up to their average peers during kindergarten year. This underlines the need of early identification and educational intervention for children with low performance (Mononen & Aunio, 2016).

10.4 Explaining the Development of Mathematics Learning with Cognitive Skills

To be able to learn, children need to focus their attention and have relevant supportive cognitive skills. Hannula-Sormunen, Lehtinen, & Räsänen (2015) have argued that those children who spontaneously pay attention to the numbers and numerical related information in their everyday environment (i.e., spontaneous focusing on numerosity; SFON) are able to learn more mathematics skills, and thus become better in those skills than children who pay less attention to the numerical information. They showed that children's early numerical skills, including SFON, before school age were important contributors to later success in school mathematics.

Also in a longitudinal setting, McMullen, Hannula-Sormunen, and Lehtinen (2015a) showed that children's SFON tendency before school age is a strong predictor of later rational numbers conceptual knowledge at the age of 12, even after controlling preschool number sequence skills. Grounding on this approach, McMullen, Hannula-Sormunen, and Lehtinen (2014) showed in a study on young Finnish children that their tendency of spontaneously focusing on quantitative relations (SFOR) predicted fraction knowledge, implicating that it played a role in the development of such knowledge. With a focus on the development of both the representations of the magnitudes of rational numbers and density of rational numbers in 10–12-year-old Finnish children, McMullen, Laakkonen, Hannula-Sormunen, and Lehtinen (2015b) found that children had substantial difficulties in understanding rational numbers during their first years of formal learning of rational numbers. Knowledge of magnitude representations was found necessary, but not sufficient, for knowledge of density concepts.

In a study looking at a broader set of predictors, Zhang et al. (2014) investigated a sample of Finnish children (aged 6–10 years) on how early language and spatial skills predicted arithmetic development, and whether counting sequence knowledge mediated these associations. Letter knowledge and spatial visualization, measured in kindergarten, predicted the level of arithmetic in first grade, and later growth through third grade. They also showed that these associations were mediated by counting sequence knowledge measured in the first grade.

In addition to language skills, working memory has been investigated in relation to Finnish children's mathematics performance. Kyttälä, Aunio, Lehto, Van Luit, and Hautamäki (2003) investigated the relationship between visuospatial working memory (VSWM) capacity, mental rotation, general intelligence, and early numeracy in 6-year-old Finnish children. Their results showed counting skills to correlate with VSWM capacity, and numerical relational skills with general intelligence. Kyttälä, Aunio, and Hautamäki (2010) further studied the possible deficits in working memory (WM), language and fluid intelligence that seem to characterize 4- to 6-year-old Finnish children with poor early mathematical skills. Children with early mathematics difficulties showed inferior verbal and visuospatial WM skills as well as lower language skills and a fluid intelligence performance. Extending the previous work, Kyttälä, Aunio, Lepola, and Hautamäki (2013) analyzed the predictions of verbal WM, VSWM, and language skills on young children's (4–7 years) ability to solve mathematics word problems. The results showed that verbal WM did not have a direct effect on word problem solving in children, but was indirectly related to performance in word problems through vocabulary and listening comprehension. These results suggest that in young children, verbal WM resources support language skills, which, in turn, contribute to variation in solving word problems. The results also showed that VSWM had a direct effect on performance in word problems, suggesting that it plays an important role in the process. Focusing on adolescents, Kyttälä (2008) investigated whether the VSWM skills of Finnish students with difficulties in mathematics differ from those of their average achieving peers. The results indicated a general VSWM deficit in students with both mathematics and reading difficulties, and a specific VSWM deficit (i.e., less capacity for storing passive visual simultaneous information) in students with only mathematical difficulties. Similarly, Kyttälä and Lehto (2008) studied passive and active VSWM in relation to mathematics performance in Finnish students, aged 15–16 years. Fluid intelligence and passive VSWM accounted for variance in overall mathematics performance. Active VSWM exhibited significant correlations with mathematics performance, but in a series of regression analyses most of its effect was observed to be mediated by fluid intelligence.

To sum up, Chinese and Finnish researchers have focused on somewhat different aspects of mathematical skills development. Perhaps in future, comparative studies on these topics with Chinese and Finnish children can be conducted to better understand the possible universal nature of these factors and their role in mathematics development.

10.5 Mathematics Learning, Motivation, and Well-Being Among Chinese and Finnish Students

The connection between motivation and learning outcomes is relatively well established. Students who are more engaged are more likely to engage in effective learning strategies (Krapp, 2007), better achieve and maintain conceptual change (Cordova, Sinatra, Jones, Taasoobshirazi, & Lombardi, 2014), show higher level of self-regulation and effort (Lee, Lee, & Bong, 2014; Trautwein, Dumont, & Dicke, 2015), and spend more time on learning tasks (Ainley, Hidi, & Berndorff, 2002). However, the causal ordering or longitudinal developmental dynamics between these factors are less well established. In the following, we will provide a brief overview of such findings from Finnish and Chinese studies.

10.6 Motivation Influencing Mathematics Performance and Vice Versa

When examining the interplay between motivation and achievement, three different models can be considered: skill development model (motivation influencing achievement), self-enhancement model (achievement influencing motivation), and reciprocal effects model (motivation influencing achievement and vice versa). In general, most support has been found for the reciprocal effects model, although the effects from achievement to motivation seem to be stronger than the other way around. This also seems to be the case in Finland and among students of different age. However, the presence of these effects also seems to depend on what is measured and how. While findings from studies by Aunola et al. (2009) and Viljaranta et al. (2014) support the reciprocal effects model, the results from Nuutila et al. (2018) study did less so. They found considerable consistency in motivation and performance across tasks and over time, but, unexpectedly, only previous performance predicted later success expectancy. Task motivation and performance did, however, predict future intrinsic value and self-concept in mathematics, thus suggesting that students' task-related motivational experiences contribute to their domain-specific beliefs, and that those, in turn, become manifested in students' task motivation. Similarly, in a study by Korhonen, Tapola, Linnanmäki, and Aunio (2016), motivation, and particularly interest, predicted later educational aspirations in adolescent students, although the effect varied slightly between boys and girls.

Another approach to the given theme has focused on the developmental trajectories of motivation and performance over time. In one of the few studies of this kind, Niemivirta & Tapola (2017) looked at how the development of children's mathematics interest and competence perceptions linked to each other and achievement over the first years of formal education. They found that both mathematics interest and competence perceptions decline over time, and these developments are strongly correlated. The decline was, however, less steep for those with higher previous achievement in mathematics. Later mathematics achievement was predicted not only by previous achievement, but also by both the level and rate of change in perceived competence. These results resemble those found in relation to the dynamics within one task (Niemivirta & Tapola, 2007).

These findings suggest that motivation plays a role in skill development, but that this effect varies depending on the type of motivational construct studied. It would seem that competence beliefs are more closely linked to achievements, and that they also contribute most strongly to further learning. Interest, instead, seems to be more linked to choices and aspirations, although they are developmentally closely linked to perceptions of one's ability. However, increases in both interest and competence perceptions over time might facilitate skill development. This might be of particular importance when looking at findings on learning difficulties and negative emotional experiences such as anxiety. Evidence namely suggest that learning difficulties and experiences of anxiety are linked to both inferior performance (Hakkarainen et al., 2012; Kyttälä & Björn, 2010; Tuominen-Soini, Salmela-Aro, & Niemivirta, 2012) and drop-out (Hakkarainen, Holopainen, & Savolainen, 2015; Korhonen, Linnanmäki, & Aunio, 2014). Moreover, these effects seem to be partially dependent on the type of goals students' strive for. Performance goals as opposed to learning goals seem to increase the experiences of strain and anxiety (Husberg, Aunio, Vainikainen, & Niemivirta, 2017; Tuominen-Soini, Salmela-Aro, & Niemivirta, 2012). This echoes the findings of one of the few Chinese studies on the subject by Rao, Moely, and Sachs (2000).

The studies demonstrate both the developmental connections between different motivational forces, how they are linked to skill development and performance, and the role well-being plays in these processes. As to the causal links, the results are far from definite. The influence of performance on further motivation seems to be stronger than vice versa, but the effects might vary as a function of students' age and educational context. Although most studies also show an overall decline in students' motivation, a lesser decline seems to operate as buffer against inferior achievement. It is nevertheless clear that performance and skill development in mathematics are a function of various cognitive and motivational factors, and that all these further contribute to students' well-being. What is less known concerns cultural similarities and differences in these developmental dynamics, and how these processes could be supported within any given educational context.

10.7 The Role of Cultural Background in Motivation

Finnish and Chinese students have both demonstrated outstanding performance in international comparisons of educational achievements. Yet, the countries represent two quite different cultural contexts—individualistic and collectivistic, respectively—and rather different kinds of educational systems, due to which the question "why" becomes of particular interest. Despite their differences, the two countries are similar in the sense that in both countries socioeconomic status explains rather little of the variation in students' achievements, and in spite of their high average level of performance, the students from both the countries seem to display lower motivation for achievement than students of other countries. Even so, research findings would nevertheless predict rather considerable differences in motivation between Finnish and Chinese students in relation to the quality of motivation and how it contributes to achievement.

A comprehensive review by Hau & Ho (2010) summarizes these differences from several perspectives. They note that while studies show that Western students value education and achievement in terms of personal utility and importance, Chinese students are likely to accompany this with a strong sense of social obligations, that is, in terms of both fulfillment of oneself and contribution to society. On the one hand, then, Chinese students are propelled by a sense of obligation to their parents, the family, and society, and on the other hand, they also clearly see the importance of education as a means for personal cultivation and perfection. Similarly, in relation to intrinsic and extrinsic motivation, research suggests a more prominent role of internalized values and beliefs related to schooling than personal interest in accounting for academic success in collectivistic cultures. In other words, unlike in western countries, intrinsic and extrinsic motivation is not necessarily seen as antithetical, but rather something that co-occur (Niemivirta et al., 2001). Consequently, among Western students, effort seems to be coupled with intrinsic motivation, whereas Chinese students appear to be willing to exert effort on tasks of even low interest or under external pressure.

One area of motivation, where Finnish and Chinese students appear rather similar concerns their relatively low competence perceptions, particularly, when compared to their western peers (OECD, 2017). This might have to do with similarities in certain cultural codes. Western students nurtured in an individualistic culture commonly experience pride upon success and low self-worth upon failure, when their emphasis in learning is on personal achievement. In contrast, Chinese students are to remain humble upon success and feel guilt and shame upon failure, due to their emphasis on learning as a duty to self and duty to the family and society. Although this cultural explanation might not entirely apply to the Finnish context in terms of the predictive mechanisms, modesty is nevertheless traditionally seen as a virtue in Finnish culture. When the above factors are considered in concert, it is not unexpected that among Chinese students, goals related to mastery and performance seem to be somewhat strongly connected, while among Western students, they are commonly found to be rather orthogonal (for a series of studies on these relations among Finnish students, see Niemivirta, 2002; Tapola & Niemivirta, 2008; Tuominen-Soini, Salmela-Aro, & Niemivirta, 2008, 2011, 2012). This might be due to the Chinese students attempting to master the materials and outperform peers at the same time in a competitive learning environment, while also striving to gain recognition from significant others. Such socially oriented learning goals, that is, striving to satisfy affiliation or recognition needs, however, constitute an important dimension that has not been well articulated in Western research on goals.

All in all, there seems to be a multitude of reasons why the comparison of Finnish and Chinese students' motivation and its role in mathematics learning and student well-being would be of particular interest and importance. Currently, however, we are not aware of any previous studies that would have compared Finnish and Chinese students in this respect, and even studies investigating the role of motivation in particularly mathematics development or performance are limited. Virtually no studies exist that would further link these to student's well-being. Thus, there clearly is an urgent need to expand current research on the given themes to cross-cultural settings.

10.8 What's Next? Exploring New Ways to Facilitate Mathematics Learning and Motivation

Next we will turn to discuss how learning in the school could be facilitated by enriching school instruction by art-based means. Most studied form of arts in this context is music: Music training is known to modulate various aspects of human behavior. In the first studies in this framework, neurocognitive performance of children who had music as a hobby was compared with children who had other hobbies. Most prominent findings indicate facilitation those aspects of behavior which are intrinsic to music such as fine-tuning of motor movements, cross-modal functions, and auditory perception (for a review, see Herholz and Zatorre, 2012). From the viewpoint of brain plasticity, this is very natural: Brain is shaped according to the training it is given.

However, later on it was observed that speech and language functions can be facilitated in musically trained children as well. If so, it indicates that music activities can train some functions which are not directly related to music as such. Most consistently, those functions consist of phonemic awareness and foreign language pronunciation (for reviews, see e.g., Milovanov & Tervaniemi, 2011; Gordon, Fehd, & McCandliss, 2015). Consequently, it has been proposed that music skills would help in learning to read. This viewpoint is supported by the fact that learning to read with Latin alphabet requires associations to be formed between a given phoneme and its symbol. If a learner is accurate in perceiving and differentiating phonemes in the auditory modality, it could be easier to obtain subsequent auditory–visual associations.

Furthermore, also more prominent development of general cognitive functions such as working memory, executive functions, and attention have commonly been observed (for review, see e.g., Moreno & Bidelman, 2014). These findings are highly important and promising: they imply that music activities could promote such high-level cognitive functions which in turn support learning of any kind. However, it should be kept in mind here that the evidence about the benefits of music for these higher cognitive functions is more heterogeneous and very likely to be biased due to the likelihood of neglecting non-significant results in editorial processes.

Here it is worth a note that the above introduced evidence is mostly obtained in children who receive individual music lessons and training in mastering one specific instrument. They (or their families) have selected their hobby and come often from families with higher socioeconomic status (SES) than the average population. To draw firm conclusions about the benefits of music in enhancing cognitive and socio-emotional skills, we should have more evidence from randomized studies. This means that there is a pool of children who volunteer to join a study and from this pool, the children are randomly allocated e.g., to music activities and to physical activities, to be considered as a control group. Unfortunately, these studies suffer from high dropout rates. For instance, in the study of Janus, Lee, Moreno, and Bialystok (2016), 72 children were recruited of whom 57 were included in the analyses of their final tests after the follow-up of 20 days. Due to high neural demands of the transfer skills to be established, it is not likely that an intervention of a couple of weeks/months could get imprinted at the neural level without very intensive training protocol. This reasoning is supported by recent findings indicating that only after two years of exposure to weekly music activities, brain responses are differentiated for musically active vs. inactive children (for review, see Kraus & Strait, 2015). Yet, it is noteworthy that in the study by Janus et al. (2016), their intensive daily music and foreign language intervention, established via summer camp activities, was successfully improving the executive functions of their 4–6-year-old children already in 20 days.

Luckily such studies following the rationale of randomization of the children to a given intervention do exist. These studies report shorter follow-up times than the studies on children with music hobbies (e.g., less than one month by Janus et al. 2016, see also below) but since they always include pretests to eliminate group differences prior to the intervention, their findings on improved neurocognitive functions can be attributed to music interventions. For instance, Moreno et al. (2011) compared the neurocognitive effects of computerized intervention for music and visual arts. The intervention lasted for 20 days and the children were asked to practice twice a day for one hour, each time. In the final analyses, there were 48 participants who were 4–6 years of age. It was found that the music intervention improved the language skills of the children and that this was paralleled with the facilitation of the neural indices of executive functions. There were no identical improvements in the children whose intervention was in visual modality. This suggests that relatively short but very intensive music intervention can improve general cognitive functions, necessary for all learning activities.

Yet, in everyday learning contexts, it is not feasible to plan using two hours of a day for a computerized intervention program in addition to or instead of school instruction. Instead, interventions which last longer and are less intense are to be preferred. As an alternative approach, several projects have internationally been established to offer music activities as extracurricular activities, e.g., Il Sistema and Harmony projects (e.g., http://sistema-toronto.ca/ and https://www.harmony-project.org/). Currently, two large longitudinal studies are currently ongoing to systematically investigate the efficacy of such intervention programs established in real-life contexts. The first results have been already launched, showing that in two (but not in one) years, those neural processes which underlie intact literacy skills are fine-tuned by music activities (Harmony project; Kraus & Strait, 2015). From Il Sistema-based intervention, we now know that it facilitates sound-related neural functions in two years from the project onset. Such a facilitation is not observed after a sport-based intervention or in control children (Habibi, Cahn, Damasio, & Damasio, 2016). The outcome of the cognitive tests has not yet been published but since the project will be monitored for total of five years, it is just a matter of time to learn more about it.

Even if the exact implications of music-induced facilitation on school-based learning are not fully investigated yet, there are many promising avenues for intervention studies combining music and other arts to school instruction. Internationally taken, this is acknowledged as "STEM to STEAM" movement, promises of which are to be seen in future.

10.9 Conclusion

The reviewed research conducted in China and Finland reveals various important factors and processes that contribute to mathematics learning. Individual differences in mathematics performance begin already in early years, and the differences tend to remain or even increase over the school years. In the long run, inferior achievement seems to lead to lower motivation and even problems with well-being, which, in turn, contribute to students' further educational choices and outcomes. These findings points out to the importance of developing effective interventions. In addition to the existing direct attempts to support mathematics learning through interventions, also arts-based interventions might prove to be successful, particularly if the objective was to facilitate student engagement. Due to the rather significant differences in the educational systems of different countries, the development of mathematics learning, the role of motivation in this development, and particularly the effectiveness of different interventions under different conditions should be tested within cross-cultural research settings. This clearly is an area of research that is currently lacking. However, as the existing research undoubtedly provides a solid stepping stone for developing such research, we may hope to see the situation changing soon.

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Chapter 11
Technology as a Catalyst for Twenty-First-Century STEM Teacher Education

Marina Milner-Bolotin

11.1 Introduction

The unprecedented access to information has dramatically affected the world of education (Spector, 2015). It spurred a serious reexamination of the knowledge, skills, and attitudes learners must acquire to function successfully in a modern society (NRC, 2013; OECD, 2016). The widespread of novel technologies has also altered *how* the society views successful Science, Technology, Engineering and Mathematics (STEM) education, the role of technology in it, and what is expected from the twenty-first-century teachers (Let's Talk Science, 2017; Luft & Hewson, 2014; van Driel, Berry, & Meirink, 2014). These developments have promoted an avalanche of educational reforms in North America, Asia, and Europe (Committee on a Conceptual Framework for New K–12 Science Education Standards, 2013; Feder, 2010; Hake, 2007; Jones & Leagon, 2014; Quinn, 2011). For example, in Canada, many provinces, including British Columbia, are grappling with the new STEM curricula (British Columbia Ministry of Education, 2015). These reform efforts are aimed at encouraging teachers to reexamine their pedagogical goals, teaching approaches, assessment practices, and the role of technology in facilitating student learning (Milner-Bolotin, 2017).

The expectations of effective use of educational technologies, pose significant challenges to both teachers and teacher educators, who often become immersed in educational environments they never experienced as learners (Milner-Bolotin, 2016a, 2016b). At the same time, there is ample research evidence that technology itself is insufficient for altering instructional practices (Cuban, Kirkpatrick, & Peck, 2001;

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Milner-Bolotin, 2017). Teachers need to acquire necessary Technological Pedagogical and Content Knowledge (TPACK) to make effective learning with technology a reality (Cuban, 2001; Koehler & Mishra, 2015). TPACK acquisition begins in teacher education and continues throughout teachers' careers (Panizzon, Corrigan, Dillon, & Gunstone, 2011; Troen & Boles, 2003). In order to examine how technology might enhance STEM teacher education for both pre-service and in-service teachers, the following questions require consideration:

1. How can emerging technologies be implemented in STEM teacher education?
2. What new opportunities do emerging technologies offer to STEM teacher educators?
3. How does one examine the effect of technology use in STEM teacher education?

To answer these questions, one needs to adopt a theoretical framework for teacher knowledge that reflects its multiple dimensions; takes into account the growth of this knowledge stimulated by technology and teacher collaboration with peers, and that is firmly situated in a teaching practice.

11.2 Toward a Novel 4D Theoretical Framework for Examining Teacher Knowledge

The theoretical frameworks guiding the investigations of teacher knowledge have changed significantly in the last century. The Pedagogical Content Knowledge (PCK) framework suggested by Shulman (1986) explored different dimensions of teacher knowledge. The frameworks that followed explored additional dimensions of teacher knowledge, such as teacher motivation, attitudes, and ability to use technology to engage students in meaningful learning (Ball, Thames, & Phelps, 2008; Harris & Hofer, 2011; Manizade & Martinovic, 2016; Milner-Bolotin, 2016a). However, while illuminating different dimensions of teacher knowledge, these frameworks are mostly *static*—they focus on the current state of teacher knowledge, while paying little attention to teachers' ability to grow. They miss the time or the knowledge growth dimension. This is a significant oversight in the twenty-first century when curricula, educational technologies, as well as expectations of teachers and students are rapidly changing. Traditional frameworks also rarely consider the effect of teacher collaboration with peers, which is especially important in the age of technology. The novel four-dimensional (4D) theoretical framework proposed in this chapter addresses this challenge by incorporating a time dimension, which allows researchers to examine the growth of teacher knowledge. The 4D framework unifies the time dimension with the more traditional dimensions of teacher knowledge, such as TPACK, Teacher Zone of Proximal Development (T-ZPD), and Deliberate Pedagogical Thinking with Technology discussed below (Milner-Bolotin, 2017). The 4D framework provides a dynamic unified perspective on teacher knowledge, in a somewhat similar way

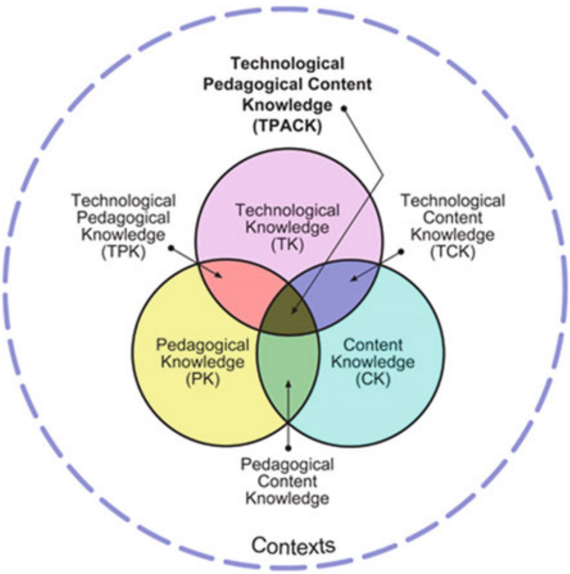

Fig. 11.1 TPACK framework as proposed by Koehler and Mishra (2009)

to how Einstein's theory of relativity provided a unified perspective on space and time. To understand the use of 4D theoretical framework to examine STEM teacher education, it is important to describe each one of its dimensions and then combine them into an overarching theoretical framework making the whole greater than the sum of its parts.

D1—TPACK: The first dimension (D1) of the 4D theoretical framework draws from the original PCK framework (Shulman, 1986). PCK framework combines Content Knowledge (CK) (i.e., specific disciplinary knowledge, such as the knowledge mathematics or physics), general Pedagogical Knowledge (PK), and Pedagogical Content Knowledge (PCK), where the latter is an overlap of the two. PCK framework was later expanded to include the knowledge of educational technologies—Technological Knowledge (TK) (i.e., the knowledge of relevant educational technologies)—thus morphing into the Technological Pedagogical (and) Content Knowledge framework (TPACK) (see Fig. 11.1) (Koehler & Mishra, 2009, 2015).

D2—Teacher Zone of Proximal Development (T-ZPD): The second dimension (D2) of the 4D theoretical framework is grounded in the research by Blömeke and Delaney (2012) that examined mathematics teachers' competencies. These researchers refer to the TPACK aspect of teacher knowledge as cognitive abilities or professional knowledge, emphasizing not only *what* teachers already know, but also their ability to acquire new knowledge. The T-ZPD dimension of the 4D theoretical framework builds on Blömeke's and Delaney's approach for describing additional STEM teachers' competencies, such as teachers' affective characteristics and ability and openness to peer collaboration (see Fig. 11.2) (Milner-Bolotin, 2017). Thus, 4D framework uses TPACK in a greater sense, focusing not only on the overlap of

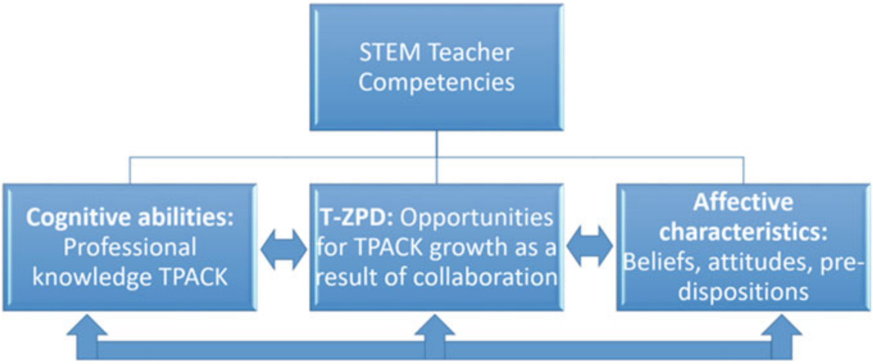

Fig. 11.2 STEM teacher competencies, as a combination of teacher's cognitive abilities, affective characteristics, and a potential for TPACK growth spurred by peer collaboration (T-ZPD)

the three knowledge domains (CK, PK, and TK), but also on the teachers' affective and cognitive characteristics, and on the teachers' ability to expand their knowledge through individual study, practice, and peer collaboration.

The 4D theoretical framework proposed here extends the original framework by Blömeke and Delaney (2012) first, by applying it to STEM teaching, and second, by considering the dynamic nature of teacher competencies. To do that, the 4D framework applies the Vygotsky's concept of the Zone of Proximal Development (ZPD) to the context of teacher education (Vygotsky, 1978): the *Teacher Zone of Proximal Development* (T-ZPD) (Milner-Bolotin, 2017). T-ZPD describes the gap between what teachers have already mastered (the actual level of development, as expressed by their current TPACK) and what they can achieve when provided with opportunities to collaborate with peers and more experienced educators. T-ZPD represents the potential for the development and growth of teachers' TPACK (see Fig. 11.3). The need to consider the dynamic nature of TPACK stimulated by teachers' interactions with peers, students, parents, administrators, and the society at large, reflects a strong belief in teaching as a professional endeavor (Tobias & Baffert, 2009; Troen & Boles, 2003). In order to keep up-to-date, teachers must always learn, update, and question their knowledge, interact with others in the field, and continuously reflect on their practice. The view of ever-evolving teaching mastery and the importance of community in becoming an effective teacher is situated in Vygotsky's sociocultural learning theory that is applicable to teacher as much as to student learning (Daniels, 2001).

It is difficult to acquire teaching skills while working in isolation (Clark et al., 1996). It is more effective to master them through apprenticeship and collaboration as is often done in Asian countries, such as China, Japan, and Singapore (Lewis, 2000; Ma, 1999). Teacher collaboration during a one-time professional development event that is not followed up by a peer collaboration focused on the implementation of novel pedagogies, rarely brings sustained changes to teachers' practice (Luft & Hewson, 2014; van Driel & Berry, 2012). In order to support teachers in adopting research-

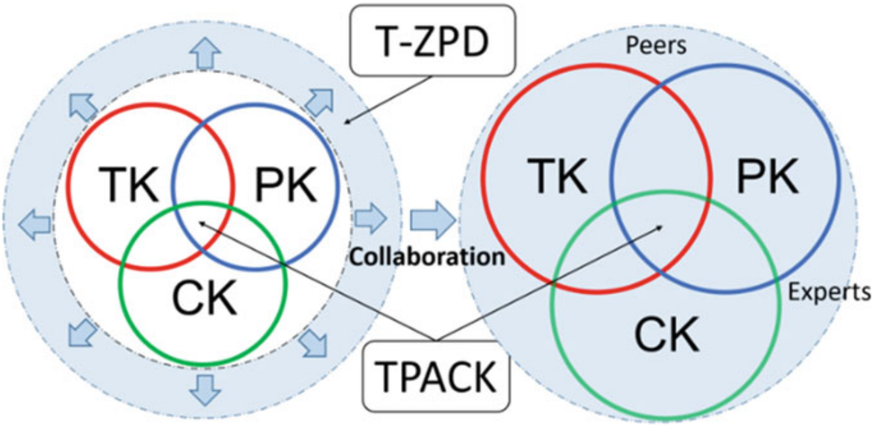

Fig. 11.3 Growth of teachers' TPACK due to collaboration with peers. The light blue ring on the left image shows T-ZPD

informed STEM teaching practices, teachers have to have multiple opportunities to inquire about their own practice, adopt and adapt new pedagogies, collaborate with peers, and acquire the necessary TPACK (Burridge & Carpenter, 2013; Krajcik & Mun, 2014; Schmidt et al., 2011).

D3—Deliberate Pedagogical Thinking with Technology: The third dimension (D3) in the 4D theoretical framework highlights the role of technology in achieving specific learning outcomes and teachers' ability to use technology deliberately to achieve specific pedagogical goals (Milner-Bolotin, 2016a). Since technology is viewed as a tool that can support meaningful student STEM engagement, the effectiveness of teacher education or professional development is evaluated through examining how teachers are able to transform student learning as a result of using technology (MacArthur, Jones, & Suits, 2011). This dimension of teacher knowledge addresses the importance of using technology with a purpose of promoting student learning. Teachers who possess extensive TPACK, but are unable to implement it into their practice, are not any more effective than their colleagues with limited TPACK. Thus, the third dimension of Deliberate Pedagogical Thinking with Technology bridges the educational theory, teacher knowledge, and practice.

D4—The Time Dimension: The fourth dimension (D4) emphasizes the growth of teacher knowledge. It allows not only to unify the three other dimensions, but also to examine how they interact and evolve, as a result of teacher education and professional development. The 4D theoretical framework (see Fig. 11.4) allows the researchers to trace the development of teacher knowledge, while paying attention to the effect of teacher collaboration, their prior knowledge, and attitudes about novel pedagogical approaches and educational technologies.

The following section presents how the 4D theoretical framework can facilitate the examination of two cases of teacher professional development: a fully online graduate program for practicing educators and an online resource of inquiry-based STEM

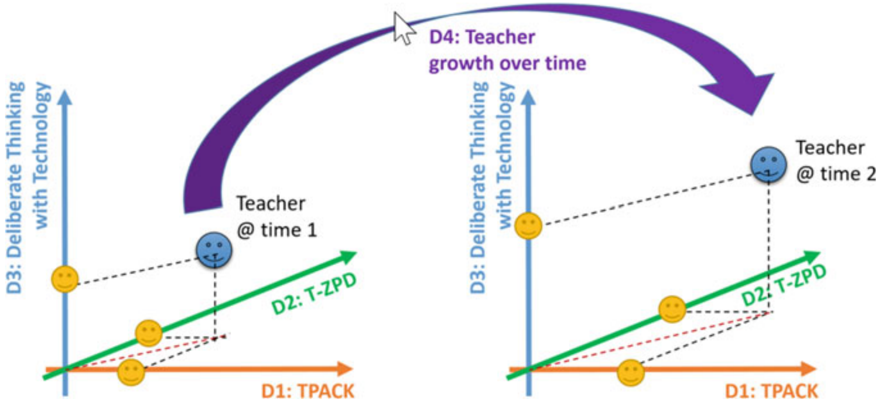

Fig. 11.4 The 4D theoretical framework for examining teacher knowledge

activities collaboratively designed by teacher-candidates (TCs), graduate students, and experienced teacher educators.

11.3 Bridging Theory and Practice Through Technology-Enhanced STEM Teacher Education and Professional Development

This section describes two examples of technology-enhanced pre-service and in-service professional development for STEM educators. These examples illustrate how 4D theoretical framework can be used in designing, facilitating, and evaluating professional development activities for STEM teachers.

11.3.1 Example 1: The Master of Educational Technology Program

Master of Educational Technology (MET) program is an internationally recognized fully online graduate program for educators at the UBC Faculty of Education (2018). Its goals are to promote informed use of technology in formal (K–12) and informal educational settings and to create a community of learners across geographical boundaries both in Canada and abroad. This is especially relevant for Canadian educators, as many of them teach in geographically remote areas. MET program attracts K–12 and post-secondary educators, instructional designers, professionals, and education leaders (currently, from more than 30 countries). Since its inception in the early 1990s, hundreds of students have graduated from it. Compared to other programs at the UBC Faculty of Education, MET is relatively small, as its online courses are limited to 24 students in order to create a vibrant online community. It also operates in a cohort form and usually takes 2–3 years to complete, as most of the students participate in it in addition to being part-time or full-time educators and are not expected to take more than two online courses per term.

While MET provides three different options to the students, most of its graduates earn a M.Ed. degree. At UBC, and in Canada in general, M.Ed. and M.A. degrees are slightly different. An M.A. degree is often pursued by educators who are interested in education research and consider pursuing a Ph.D. in the future. Thus, M.A. graduates have to carry an independent research project that will culminate in an M.A. research thesis. On the other hand, the M.Ed. degree is geared toward educators who want to continue teaching and are interested in advancing their professional knowledge and qualifications. To graduate from the M.Ed. program in British Columbia, in addition to completing all the coursework, the students have to write a graduating paper or create an online portfolio reflecting how the theoretical knowledge they acquired in the program can enhance their professional practice.

MET curriculum is designed and delivered by the faculty members who are supported by the instructional designers experienced in building and facilitating online learning spaces (Faculty of Education UBC, 2018). As any other graduate program, MET includes required and elective courses. In order to graduate, a student has to complete 10 graduate courses and create an online e-portfolio representing their learning. MET courses emphasize collaboration and reflection, while giving students ample opportunities to experience educational technologies as learners, reflect on them as teachers, and attempt to implement them in their own classrooms (Milner-Bolotin, 2015).

An example of MET curriculum includes courses exploring research methods in education, teaching and learning with technology, design and evaluation of technology-enhanced learning environments, as well as courses on specific educational technologies and educational assessment (Milner-Bolotin, 2016a). All of the courses provide multiple opportunities for the MET participants to experience various educational technologies in the context relevant to their own teaching, to collaborate and learn from each other, to provide and receive feedback from peers and from the instructors. For example, one of the courses titled *Mathematics and Science teaching and Learning through Technologies* includes the following assignments:

1. **Student-led presentation**: In collaboration with a peer, create an online presentation on one of the course topics and facilitate an online discussion of this presentation, provide constructive feedback to your peers on their online presentations and respond to the feedback received from peers.
2. **Professional development event design**: Choose a technology of interest in the context of STEM education and design an online professional development event aimed at your colleagues that will introduce them to this technology and convince them to incorporate it in their teaching. Collaborate with a peer to provide feedback to each other on the professional development events you have designed. Show how you have used your peer feedback.

3. **Educational technology debaters**: Pair up with a peer to prepare two 3-min online presentations (online debates) representing pros and cons of two different educational technologies of your choice.
4. **Educational technology design project**: In collaboration with a peer, design an activity relevant to your school's STEM curriculum that would deliberately incorporate educational technology to promote student learning.

Considering the 4D Theoretical Framework described earlier (see Fig. 11.4), it becomes clear how this course's structure and assignments are intentionally designed to address each one of the framework's dimensions. All course assignments include collaboration in the context of STEM teaching and learning to help educators move along the TPACK (D1) and T-ZPD (D2) dimensions. As part of the course, the participants learn to provide and receive feedback, to use various technologies in order to promote student learning, and work continuously on improving their pedagogical practices and theoretical knowledge. Most importantly, technology is used deliberately throughout the course to promote active engagement pedagogies, so that teachers have multiple opportunities to experience these technologies both as learners and as teachers (D3: Deliberate use of technology). Moreover, continuous reflection, feedback from peers, and multiple iterations of the assignments help course participants to experience the evolution of their knowledge for teaching—the time dimension (D4). Finally, a significant portion of the assignments give participants an opportunity to design educational materials relevant for their own practice. For example, in Assignments 2–4, the topics can be chosen by the students themselves. This gives them an opportunity to tailor their learning to their own needs and gain ownership of their learning (Enghag, 2004; Milner-Bolotin, 2001). The metaphor of ownership of learning is appropriate here as it emphasizes that the knowledge the learners acquire becomes a valuable and enjoyable possession that the owner can use at their own discretion in the context that is relevant for them (Milner-Bolotin, 2001, p. 40). In order to have ownership of learning, the students have to find personal value in what they are learning, feel in control of the learning process, and take responsibility for the learning outcomes. Reflecting on the course design, one can see that course assignments are designed to reinforce student ownership of the course and to bridge educational theory with educational practice.

The following Discussion Section examines in more detail some successes and challenges of the MET program, and considers how it can facilitate professional development for twenty-first-century STEM educators. However, prior to delving into this discussion, it is worthwhile describing a very different case of technology-supported professional development for STEM teachers. In the second example, TCs supported by an experienced faculty member and a graduate student become engaged in creating resources for other educators, while learning about new pedagogical approaches and new technologies. Thus, TCs become not only consumers of resources created by others, but also contributors and active participants of the STEM teacher education community of practice (Lave, 1990).

11.3.2 Example 2: STEM Education Videos for All Project

New British Columbia curriculum encourages teachers to design flexible learning environments that foster concept- and inquiry-based learning, doing instead of memorizing, developing big ideas, and nurturing student competencies and soft skills, such as communication and collaboration (British Columbia Ministry of Education, 2015). In order to achieve these goals, STEM teachers have to experience designing such learning environments that promote different modes of student engagement. For example, designing and facilitating STEM outreach events for the public allows future teachers to come up with engaging hands-on activities, practice science communication, and gain confidence in inspiring a wide audience in STEM. Thus, an opportunity to experience STEM outreach plays an important role in STEM learning for both students and TCs (Friedman, 2012; Let's Talk Science, 2017; Scientists and Innovators in the Schools, 2017). However, higher education institutions in general and teacher education programs in particular pay little attention to educating TCs about *how* to communicate STEM to the general public. This is particularly relevant to elementary teacher education programs, even though there is extensive evidence that engaging parents in STEM education for their children has multiple benefits for student learning (Let's Talk Science, 2015; Milner-Bolotin & Marotto, 2018; Perera, 2014).

Moreover, due to the structure of the Canadian K–12 education system and elementary teacher education, the majority of elementary teachers view themselves as generalist: in most Canadian provinces, elementary teachers teach all subjects from Kindergarten to grade 7. Most elementary teachers in Canada have little confidence and interest to engage in STEM education or outreach. Besides, due to time constraints, teacher education programs rarely focus on STEM education for elementary teachers. This makes it even more challenging for elementary teachers to facilitate high quality STEM education for their students, even though recent educational reforms have attempted to improve STEM education at the elementary level (British Columbia Ministry of Education, 2015).

UBC Faculty of Education Family Math & Science Day was founded in 2010 to address this problem and engage future elementary and secondary teachers in meaningful STEM education (Milner-Bolotin, 2018a; Milner-Bolotin & Milner, 2017). The event's goal is to engage elementary and secondary STEM TCs in designing and facilitating short inquiry activities aimed at a lay audience: preschool and K–12 students, parents, and the general public. During the event, TCs facilitate interactive hands-on STEM activities for the guests, thus practice inquiry-based teaching and STEM communication (An, 2015).

STEM communication can happen at many levels: in the classroom, during the outreach event, as well as in other informal environments. After the inaugural event in 2010, it became clear that pairing elementary TCs with secondary STEM TCs might serve many purposes. For example, secondary STEM TCs will benefit greatly from explaining big ideas to future elementary teachers before engaging with the general public. Moreover, if elementary and secondary TCs can collaborate on designing these activities prior to the Family Math & Science Day, they would be able to learn from and support each other. In addition, in the post-event focus groups, many TCs expressed their desire to facilitate similar hands-on activities in their own classrooms during their school practicum and postgraduation. They also expressed the interest in having more detailed information about the hands-on activities conducted by their peers, so they can implement them in the future. Considering there were more than 100 hands-on activities during the Family Math & Science Day, it was unrealistic to expect that every TC will be able to explore all of them.

TCs' requests were the motivation behind creation of an online database of video resources for TCs that can be used during the Family Math & Science Day, as well as in their own classrooms. The YouTube channel "Science & Math Education Videos for All" has a growing collection of almost 80 3–6 min videos of STEM experiments that TCs can conduct during the day as well as in their school practicum or postgraduation (Milner-Bolotin, 2018c). The videos are designed having teachers in mind—they focus on the STEM concepts, way to present them in an engaging way, possible extension activities, and the links to the curriculum. Most of these experiments require inexpensive equipment and can be performed in both elementary and secondary classrooms. The videos are the result of an ongoing collaboration between STEM TCs, graduate students, and faculty members (Tembrevilla & Milner-Bolotin, 2019). These videos provide a "hook" for a hands-on STEM activity that TCs can explore and implement in their own teaching. Originally, the videos were created by the faculty members with the help of a few graduate students. Consequently, these resources were incorporated into STEM methods courses in the Teacher Education Program, so TCs were asked to design their own videos and improve the already existing ones. In order to do that, TCs had to learn the basics of video editing and production as well as hone their communication skills. This assignment engaged TCs in the project not only as consumers of already existing resources, but also as valuable contributors to the STEM education community.

The establishment of the STEM methods course assignment that asks TCs to collaborate with peers in order to contribute a 3–5 min video of a STEM hands-on activity to the a video resource also helped promote continuity between consequent teacher education cohorts. Moreover, TCs feel ownership of their work. This is a very important dimension for teachers' growth, as it has been shown that learners' ownership is related to their intrinsic motivation and interest (Milner-Bolotin, 2001). In this STEM methods course assignment, every year TCs build on the work of their predecessors instead of starting it all from scratch. This project combined digital skills (video design) with creating low-tech hands-on activities. Finally, this resource is useful for TCs during their professional practice after they graduate, as the access to these videos is free. Table 11.1 shows how all four dimensions of the 4D Theoretical Framework are addressed by this assignment.

Reflecting on the 4D Theoretical Framework described above (see Fig. 11.4), it becomes clear how the Family Math & Science Day course assignment addresses each one of the framework's dimensions. In this assignment, TCs learn about new technologies, and put them in use through designing STEM videos fort teaching STEM concepts relevant to British Columbia curriculum. Thus, technology is used in order to promote TCs' TPACK (D1). TCs collaborate on designing the videos, provide peer feedback, and use the videos during the practicum and the Family Math & Science Day (D2: T-ZPD). The entire assignment emphasizes the use of technology as a vehicle for promoting teacher's knowledge. TCs use video editing tool to share their TPACK with colleagues and to promote active student engagement in STEM classrooms (D3). Finally, as a result of producing resources for STEM teaching, TCs begin to think of themselves not only as consumers of the available educational resources, but also as contributors to the STEM education community. Anonymous positive course evaluation feedback and ever-growing numbers of TCs who participate in the annual event attest to TCs' realization that this assignment contributes to the growth of their knowledge for STEM teaching. (D4: the time dimension).

11.4 Discussion and Analysis

The previous sections have described how the 4D Theoretical Framework can serve a useful guide for teacher educators in bridging STEM educational research and teacher education practice. However, every educator knows that the road from educational theory to the actual teaching practice is not always as straightforward as one might have liked. While designing innovative curricula, educators often need to go through multiple iterations and even then, these curricula have to be adjusted to the individual learning context. This section describes the author's reflections on the challenges and opportunities experienced during the actual implementation of the two professional development opportunities mentioned above.

11.4.1 Reflections on the MET Program

The UBC MET offers valuable opportunities for STEM educators interested in exploring how novel technology-enhanced pedagogies can influence their own practice. The MET program's research focus and deliberate pedagogical design help its participants to reexamine their pedagogical practices and build confidence with using novel technology-enhanced pedagogies (Jonassen & Land, 2012). Moreover, as the program is geared toward practicing educators, the assignments challenge the participants to collaborate on designing learning environments that incorporate technology-enhanced pedagogies discussed in the program. This helps the program participants to have ownership of technology-enhanced pedagogies while connecting theory and their own practice (Milner-Bolotin, 2001). This is particularly relevant for the teachers who work in small remote schools and who do not have colleagues who can support them in implementing innovative curricula. In the era of rapid technological changes and high expectations from teachers to incorporate technology, this is an invaluable opportunity.

Program's flexibility in terms of the mode of delivery, the choice of courses, projects and educational technologies coupled with ample opportunities for collaboration with educators from all around the world are unprecedented and highly valued by both the program participants and instructors. As one of the graduates remarked: "*When a document begins in British Columbia, is refined in China, polished in Ontario, proofed in Japan, and submitted from New York, you know you've been part of a truly global learning experience.*" The participants also appreciate the quality of their educational experiences, as program is adjusted and improved continuously to incorporate educational innovations, address current educational trends and reforms, and respond to student feedback.

However, as any other educational opportunity, the MET program has its own challenges. The most notable one is its cost, which limits its affordability for many educators, especially the ones teaching in disadvantaged areas. Unlike free Massive Open Online Courses (MOOCs) that offer professional development opportunities, MET is rather expensive as it takes a personal approach to each student. It would be interesting to see if modern technology can help create MOOCs for teachers that can offer opportunities for educators around the world to collaborate and expand their pedagogical practices. So far, the MET is a rather expensive professional development opportunity for teachers as compared to other short-term programs that do not grant graduate degrees. Unlike the educational systems in other countries (for example, in China) in Canada, limited resources are dedicated to teacher professional development, thus, placing the burden of funding professional development almost entirely on teachers. Table 11.1 summarizes some challenges and opportunities of the MET program based on the anonymous student feedback collected through course evaluations and the author's personal experience (Milner-Bolotin, 2014). While this is somewhat limited data, it highlights a number of challenges. It also shows that the same factors can simultaneously present challenges and opportunities. For example, the program's online delivery is a great opportunity for both the students and instructors to learn in a flexible manner. At the same time, it can also be a challenge if the students and the instructors are not well organized, do not know how to manage their time, or if the program is not well structured.

The MET program is an example of a graduate professional development opportunity for educators, many of whom are STEM teachers, that is built to promote all four dimensions of teacher knowledge. From expanding teachers' TPACK (D1), to engaging them in collaborative technology-rich learning environments first as students and then as teachers (D2), to challenging teachers to think about deliberate use of education technologies to promote student active engagement (D3), and finally, through challenging educators to design and implement these learning environments in their own classrooms. Throughout the program, teachers have ownership of their learning both in terms of the process and of the final product. However, the MET program has some challenges (see Table 11.1). For example, since this professional development opportunity is funded by the teachers, this limits the program's affordability. It is also more expensive than comparable face-to-face graduate programs. As indicated by the program participants in their anonymous program evaluation, this is an issue for many of them. However, since the program participants often advance in

Table 11.1 Challenges and opportunities of the MET program

	Opportunities	Challenges
For instructors	Growth in all four dimensions of teacher knowledge Implement innovative pedagogies Collaborate with motivated peers Flexible course delivery Design relevant assignments Conduct research on novel technology-enhanced pedagogies Inspire STEM educators	Labor and time intensive Extensive preparation, planning Design innovative assignments Flexible course delivery Continuous student engagement Ongoing mentorship, formative evaluation, adjustment Challenging program design
For students	Growth in all four dimensions of teacher knowledge Earn a graduate degree: career advancement, leadership Personally interact with instructors Learn through collaboration with international peers Flexible course delivery Learn while working full time and raise a family Design learning environments for your students (ownership)	Labor and time intensive Requires openness to collaboration, accepting and providing critical feedback Can be overwhelming for full-time educators Challenges common thinking Relatively expensive (compared to face-to-face programs) Requires creativity and continuous learning about and implementing innovative pedagogies

their careers after graduation, this is a big enough of an incentive for many of them to participate.

Another significant challenge for tuning the MET program into a life-long professional development opportunity for teachers is the lack of the formal follow-up with the participants after graduation. After the program is over, the participants are not likely to continue their collaboration or to keep in touch with their instructors. While there is an email list of all the program graduates kept by the MET administrative office, it is insufficient to keep the community going. There is no ongoing professional community for the program's. Therefore, one of the current MET goals is to create a program's "postgraduate extension," such as professional development and collaboration among teachers that began during the program will continue throughout their careers.

One possible way of addressing this challenge might be to initiate collaboration between the MET program and the school districts where many of the program participants come from in order to support program graduates in becoming leading teachers in their own school districts. This model is used in many countries, including the United States, Canada, and a number of European countries (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). For example, in Israel the concept of leading or master teachers is very common (Liberman, Kolikant Ben-David, & Beeri, 2012). Leading teachers are the teachers who have experienced additional professional development, mastered desired pedagogical skills, and are tasked with leading their peers to change their practices. It is well established that teachers can be very successful at leading their peers through change as they know first-hand what this change meant for them and they have similar experiences to their colleagues (Bogler & Somech, 2004). This can be an untapped opportunity for the MET program: to create an international network of teacher-leaders who are ready to support their peers in successful technology implementation.

An additional challenge for the MET program is to conduct an ongoing formative and summative assessment of its effectiveness based on the long-term impact on the program's graduates. It is important to examine (a) how these graduates are able to improve their professional knowledge, pedagogical strategies, and attitudes about using the results of educational research in their teaching, and (b) how these graduates are able to make an impact on their local professional communities. While currently, the program collects anonymous course and program evaluations, no rigorous feedback is available on how program participants are able to alter their teaching practices and make a difference in their classrooms, schools, and districts. This is an opportunity for future research.

11.4.2 Reflections on the STEM Education Videos for All Project

Unlike the fully online MET program for graduate students who are already practicing teachers, the *STEM Education Videos for All* project was an assignment in the STEM methods courses in the face-to-face UBC Teacher Education Program (Milner-Bolotin, 2018c). In this assignment, technology was used to support the TCs working in teams of 2–3 in designing educational videos of STEM inquiry-based activities that TCs used during the Family Math & Science Day (Milner-Bolotin & Milner, 2017; Tembrevilla & Milner-Bolotin, 2019). Thus, technology was a tool that supported TCs in developing all four dimensions of teacher knowledge (see Fig. 11.4): their TPACK (D1), T-ZPD (D2), deliberate use of technology (D3), and finally, their ability to reflect on their personal growth as educators (D4). Although the Family Math & Science Day was founded in 2010, the *STEM Education Videos for All* project was only piloted in the fall of 2016. It was fully implemented for the first time in the fall of 2017. While the project is ongoing and the analysis of the TCs' feedback has not been completed yet, the anonymous course evaluations and interviews with TCs show that it was one of the most meaningful experiences for them in the program. For example, many of the TCs refer to the project in their teaching philosophy statements and put it on their resume. More data needs to be collected to draw the final conclusions. However, the hope is that as the number of TC volunteers in the Family Math & Science Day grows (in 2017, it has increased by more than 60% as compared to 2016), the *STEM Education Videos for All* resource will keep growing and be used by a greater number of TCs. Moreover, based on the quality of created resources and TCs' feedback, we have some preliminary evidence of the positive pedagogical impact of this resource on TCs. Table 11.2 summarizes some

Table 11.2 Challenges and opportunities of the *STEM Education Videos for All* Project

	Opportunities	Challenges
For instructors	Growth in all four dimensions of teacher knowledge Course continuity and growth TCs' support: Building resources for classroom, practicum, outreach TCs' support beyond the classroom: fee online resources Community around technology-enhanced STEM education Personal satisfaction Conduct research on novel technology-enhanced pedagogies Inspire STEM educators	Labor and time intensive: It takes time, expertise, and skills to produce high quality videos. Requires continuous scaffolding and mentoring Instructors have to learn new tools, e.g., video editing technology Initial funding: Some support is needed to start the project Adaptability to different levels of skills in TCs and instructors Resilience and patience
For students	Growth in all four dimensions of teacher knowledge Author STEM resources to be used by other educators (ownership) Benefit from STEM resources designed by peers Gain skills & confidence for designing STEM resources Learn to collaborate with teachers Appreciate inquiry-based teaching Personal satisfaction Become members and contributors to STEM education community Ongoing reflection and flexibility	Labor and time intensive: It takes time, expertise, and skills to produce high quality videos. Can be challenging for TCs who have never created/edited videos TCs have to learn new tools, e.g., video editing technology TCs have to learn to think of pedagogy first and technology second (4D Framework) TCs have to be open to collaboration, mutual feedback, and support TCs have to develop patience Ongoing reflection and flexibility

challenges and opportunities of this project, based on the initial implementation. This information is gleaned from the anonymous course evaluations, interviews with TCs, and personal teaching experiences of the author and of the graduate students involved. While we realize we cannot generalize from these data, the information is still valuable.

In summary, the second example of using educational technology to promote TCs' personal growth has revealed the importance of TCs' ongoing engagement in a project driven by their own interests and aimed at designing resources for their future teaching that can be shared with their colleagues. TCs' ownership of the educational resources was an important aspect of the *Education STEM Videos for All* project. Based on TCs' course evaluations, their engagement with designing new resources was important for helping them build their own knowledge for teaching, as described by the 4D Theoretical Framework, their confidence, and slowly embrace inquiry-based STEM pedagogies.

11.5 Conclusions and Future Research Directions

The overarching aim of this chapter was to explore how modern technologies can become catalysts for design, implementation, and evaluation of effective STEM teacher education opportunities for both pre-service and in-service teachers. In order to accomplish this goal, two specific tasks were set: (a) to develop a novel theoretical framework for examining STEM teacher knowledge; and (b) to use this framework to design, implement, and evaluate two different examples of STEM teacher education and professional development opportunities.

A novel theoretical framework, 4D Theoretical Framework for examining knowledge for teaching, was proposed in the chapter. The 4D Framework focuses on four dimensions of teacher knowledge (see Fig. 11.4): the TPACK (D1), the T-ZPD (D2), the Deliberate pedagogical thinking with technology (D3); and the Knowledge growth (time) dimension (D4). Unlike other theoretical frameworks, the 4D Framework focuses not only on the acquisition of knowledge by teachers (D1), but also on the teachers' ability to learn through collaboration (D2) and think deliberately about the use of technology to promote student learning (D3). Most importantly, the 4D Theoretical Framework pays careful attention to the growth of knowledge for teaching. Thus, it acknowledges the dynamic nature of teacher knowledge. This is especially relevant for twenty-first-century educators who live in the time of rapid changes of curriculum, expectations from teachers and students, as well ever-changing educational technologies. While this framework can be applied to the study of teacher knowledge in general, in this chapter, it was specifically applied to the examination of STEM knowledge for teaching.

The 4D Theoretical Framework was applied to examine the design and implementation of the UBC Master of Educational Technology online program for in-service teachers and a *STEM Education Videos for All* project in UBC STEM Teacher Education Program for preservice teachers. Through reflecting on two different but complementary cases of technology-enhanced STEM teacher education and professional development, it became clear that technology can become a powerful catalyst for designing and implementing effective professional development experiences for STEM teachers. Moreover, it is imperative that both preservice and already practicing teachers experience and reflect on technology-enhanced learning environments as learners before they are ready to implement these environments as teachers in their own classrooms. In both examples, educational technology facilitated the engagement of STEM educators in collaborative design of technology-enhanced STEM education resources relevant to their teaching contexts. In addition, teachers had an opportunity to reflect on the theoretical underpinnings behind these resources, the purpose of using specific technologies, the ways the pedagogical effectiveness of these resources could be evaluated, as well as on their own learning in these learning environments. The opportunity to collaborate, provide and accept peer feedback, examine, and reflect on their learning was essential for helping educators to gain ownership of the technology-enhanced educational materials they were designing. Thus, educational technology has become a catalyst for designing educational resources and empowering teachers to adapt their pedagogies to the twenty-first-century students.

While there is extensive research investigating student ownership of learning and the impact of ownership on student achievement (Enghag, 2004; Milner-Bolotin, 2001; Polman, 1999), there has been insufficient attention paid to the teacher ownership of classroom activities and pedagogical approaches teachers choose to implement in their classrooms. This can be a potentially fruitful venue for future research: investigating the impact of teacher ownership of educational resources and enacted pedagogies on their openness to implementing these pedagogical approaches in their practice. Teacher ownership might also have an impact on their perseverance in the case when the initial implementation of novel pedagogical approaches has limited success (Milner-Bolotin, 2018b). Another potentially fruitful venue for research is examining how teacher professional development based on the 4D Theoretical Framework can facilitate the growth of teacher ownership of novel technology-enhanced pedagogies.

The current chapter shed light on two examples of technology-enhanced teacher education and professional development situated in Canada. However, the educational systems in other countries are rather different. For example, Chinese teachers receive extensive support in terms of professional development opportunities. They are also much more open to school collaboration than their Canadian counterparts (Ma, 1999). Therefore, it might be especially interesting to use 4D Theoretical Framework to conduct a study that will compare existing professional development opportunities and STEM teacher knowledge available to Chinese and Canadian teachers, the role of technology in STEM teacher professional development, and how these professional development opportunities affect the enacted practices in their classrooms.

Recently our research team has piloted a study that investigated Chinese, Korean and Canadian teachers' attitudes about the role of technology in their teaching. Not surprisingly, this study indicated significant differences between these educators (Milner-Bolotin & Oh, 2016). These findings might lead to profound implications for STEM teacher professional development and teacher engagement with technology. Answering these questions requires an international collaboration, which will be implemented in the follow-up study.

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Chapter 12
Shifting Pedagogies and Digital Technologies—Shaping Futures in Education

Jon Mason, Greg Shaw and Dian Zhang

12.1 Introduction

The transformation of education driven by innovations in digital technologies has been happening for around three decades, although in different waves and marked by moments of disruption. The increasing number of academic journals, industry reports, and media commentary on this topic all testify to this. Much of the transformation is global in scale; however, local and cultural differences will likely prevail for a long time yet. Moreover, transformation is more visible within the higher education and vocational training sectors than for school education, where there is less scope for organisational change. As our case studies indicate, transformation of education is also more prominent in the developed world.

As educators working within higher education, we bring a specific interest in pedagogy to this discussion. Our combined experience of working in this sector for many decades is that the net effect of change brought by technological innovation both enhances and disrupts established practice. If one story were to be told, then it is a story of a major shift from didactic teaching towards student-centred approaches. One story is not sufficient in the real world, however, and our case-studies reveal changes manifest in diverse ways.

Planning for our future is quite a normal thing for people to do. We think about our future and trying to organise our lives for it, or at least as we envisage what our future might be, and what we hope for. We do not always get our planning right—the best laid plans of mice and men often go awry. Organisations and individuals both undertake planning, for example, the strategic planning processes that companies and

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educational institutions often undertake. Strategic planning, as a response to social need and public policy, is about making informed decisions in relation to where an institution wants to be, what it wants to do and how it will do this. In other words, it is future planning.

As an exercise in future planning, strategic planning is also an exercise in futures thinking. There are limits, however, because such planning is typically concerned with only a specific aspect of futures thinking—articulating a preferred future.

As teacher educators, educational technologists and educational researchers, our planning for and thinking about our futures needs to be vigilant about two things: the dynamics of change in our own field, as well as the dynamics of change in our own personal development. This therefore requires us to routinely consider and to reconsider the impact of technological change not only within teacher education but at all levels of education, as well as the impact of technological change in our own lives.

So why might a consideration of strategic planning be useful in introducing this chapter on shifting pedagogy? There are several reasons for this, but foremost we wish to highlight the context of educational organisations having responsibility in responding to and guiding change—and, that culture within an organisation is often the most critical factor for determining success. Technology might enable a meaningful shift in pedagogical practice but if the organisational culture and individuals' beliefs and practices do not support or promote such change, then it is unlikely to take place. Also, change is more likely to be successful when people to be affected by change are involved in bringing about the change. This incorporates some aspect of culture dependent inertia but it is also about ownership and engagement—or, in other words, stakeholder buy-in.

Context is also often rich in other information and dynamics and organisations do not operate in isolation—social, political, economic, cultural and increasingly global influences all have an impact. Likewise, systems developed in earlier times to respond to a different set of influences can also shape the context and the options available for managing change. Some systems persist while others become obsolete. In their time, talking drums and smoke signals were effective means of communicating across large distances and can be understood as communication technologies that combined innovation with systems and protocols (Gleick, 2011). Today, the challenge of distance is rarely a problem for human communication and innovations in information and communications technology (ICT) have had a profound impact on global socio-economic dynamics and a transformational impact on education.

While educational technology has a deeper history, the origins of the digital revolution are more recent. Thus, Fig. 12.1 presents a snapshot of some key historical moments in the ongoing digital revolution (following Mason & Pillay, 2015).

The moments represented in Fig. 12.1 are only intended to be a snapshot and many other prominent moments can be identified. Moreover, this arrow could be interpreted as representing gradual change; but, many of the moments depicted are also associated with unprecedented and significant drivers of change and shifts in practice. As a timeline, however, Fig. 12.1 also provides an opportunity to consider these events in a historical context. What can we learn from historical perspective?

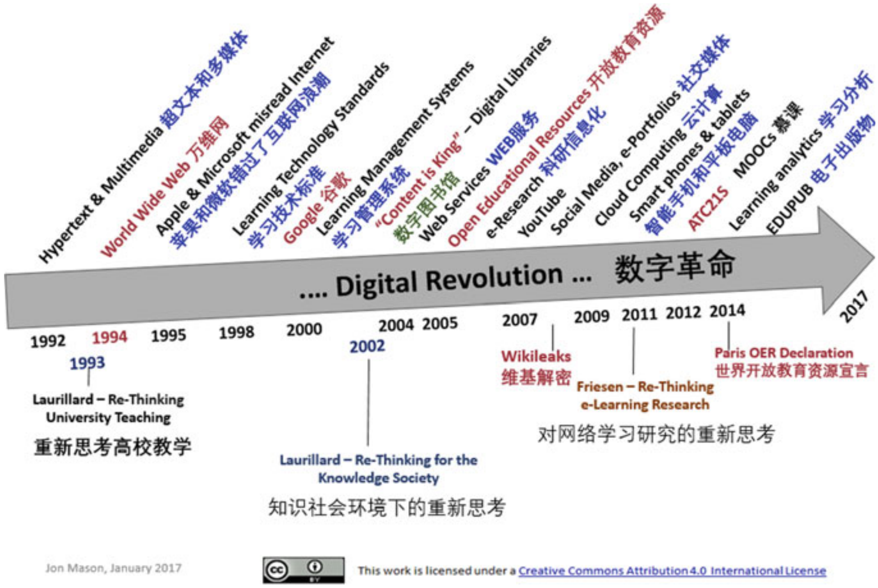

Fig. 12.1 Key moments in the digital revolution

Over a decade ago at an international event focused on positioning for the future Bell, Martin, and Clarke (2004) noted:

> e-Learning has been frequently heralded as a transforming influence on global education and corporate training. Despite such rhetoric, the adoption, diffusion and exploitation of e-Learning by educational institutions and organizations have been slower than anticipated. (p. 296)

Arguably, this statement is still a valid characterisation in some contexts today.

12.2 Technological and Pedagogical Change

When considering the broad discourse on technology-enabled learning and pedagogical change that has taken place in recent decades and that leads us towards possible futures, we focus the following discussion within a futures frame. This is necessarily broad because educational technology is intrinsically and increasingly a multidisciplinary field drawing from disciplines such as educational theory, computer science, information science, instructional design, psychology, communications, social science and artificial intelligence. A specialised focus in recent years includes data science. Thus, Friesen (2009) argues that as an academic discipline, e-learning must be 'an inter- or cross-disciplinary endeavour' (p. 20), a view consistent with other perspectives from contemporary literature on e-learning (Anderson, 2011; Dirckinck-Holmfeld, Hodgson, & McConnell, 2011; Herrington, 2009).

12.2.1 Technological Change

Understanding technology-enhanced learning also *demands* historical perspective. Why? In short, change is not linear and numerous trajectories of change are made possible through technological innovation, and by the ways that we respond to and influence change because of our social and cultural positions. When reviewing Fig. 12.1 of the Key Moments in the Digital Revolution and the literature associated with elaborating on it, some key narratives in respect to digital technologies in education are identified as prominent over this period:

- the transformation of education arising from innovations in digital technology (Tuomi, 2013; Garrison & Akyol, 2009; Kellner, 2004; Hanna & Latchem, 2002; Laurillard, 1993);
- the profound impact of networks on learning (Steeples, Jones, & Goodyear, 2002; Hiltz & Wellman, 1997);
- the rise of standardisation in technical infrastructure, teacher accreditation and student achievement (Thomas & Knezek, 2008; Friesen, 2005);
- a growing agenda concerned with open educational resources and practices that has disrupted traditional business models associated with publishing, access to content and credentialing and deployment of services based upon knowledge sharing (Daniel, 2012; Blackall, 2009; Laurillard, 2008; Tuomi, 2013);
- a shift from concern with content knowledge towards the development of '*21st century skills*' and processes (Roseth, Valerio, & Gutierrez, 2016; McGaw, 2013; Voogt, Erstad, Dede, & Mishra, 2013; Soland, Hamilton, & Stecher, 2013; Bellanca & Brandt, 2011);
- a shift from teacher-centred to student-centred pedagogies (Tondeur, van Braak, Siddiq, & Scherer, 2016; Beetham & Sharpe, 2013);
- progression from the learning management system as the centrepiece of e-learning system's infrastructure within formal educational institutions towards on-demand services in which the individual must also engage within a data-rich environment but is challenged by loss of privacy (Mason & White, in Press; Sclater, 2008).

Each of these narratives speaks to key trends, their dynamics and interrelationships.

Similarly, the future of learning facilitated by digital technology has thus been imagined diversely for over three decades, and arguably longer. Because ongoing innovation typically brings positive economic benefit, these futures are often described in terms of the digital economy (Wyckoff, 2016). Sometimes, however, these futures are also described in dystopian terms in which negative social consequences are imagined (Virilio, 2005). It is now commonplace to see policy documents

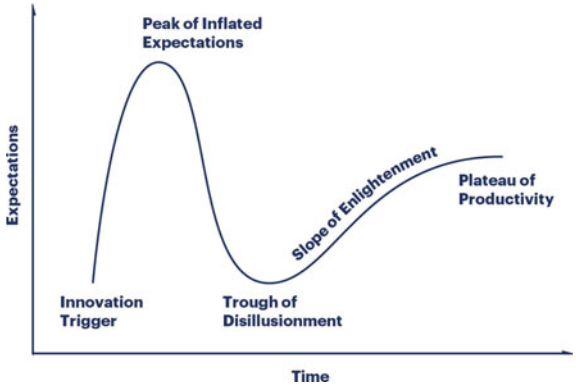

Fig. 12.2 Gartner methodologies, hype cycle https://www.gartner.com/en/research/methodologies/gartner-hype-cycle

that use phrases like 'future ready' (US Department of Education, Office of Educational Technology, 2016). It is certainly the case that overworked and vague terms like '*21st century skills*' are embedded into both academic and public discourses. And, as we move into the so-called era of big data, scholars are seeing new affordances of digital technology where ubiquitous data points are enabling learners to become researchers of their own learning (Cope & Kalantzis, 2015), and enabling teachers to have new perspectives of learner behaviour. Behind and beyond these data points, however, are the algorithms embedded with Internet infrastructure—as Pasquale (2015) describes it: 'Pattern recognition is the name of the game—connecting the dots of past behavior to predict the future' (p. 20).

To ground thinking about the future, structured planning processes are used to inform and prepare strategic activities that might optimise outcomes. A typical example from contemporary context can be found in the literature associated with learning analytics and big data. On the one hand, there is a growing discourse associated with the benefits to both teaching and learning; while on the other hand, there is disquiet concerning potential loss of privacy and the emergence of the surveillance society or 'black box society' (Pasquale, 2015; Zuboff, 2015) (Fig. 12.2).

As we have already alluded, identifying plausible futures that can inform the development of strategic planning is a common task within organisations.Whether this is through the articulation of a five-year strategic plan, a professional learning plan of an individual employee, or simply a teaching schedule that considers the immediate learning needs through a sequence of lessons, the future is imagined as a desitination.

Much of the hope and hype associated with what is possible, however, is determined by context. In Australian education, this context can be described in terms that indicate a relatively recent national approach to the development of infrastructure and services for education and training—such as a national school curriculum and national teacher competency standards. Futures can also be described in terms of a readiness to embrace innovation. Waves of ongoing innovation with digital technology have provided both opportunities and challenges for Australian education and training—particularly in terms of collaboration in learning, disruption of learning and transformation of the learner.

Because hype is routinely associated with technological innovation Gartner (through one of its lead consultants) developed the *Hype Cycle* in 1995 and has been applying it in their reports ever since. A recent example focused on 'emerging technologies' can be easily located on a web search. Despite its success in the world of management this depiction of how the market views and adopts technologies does not necessarily assist the actual planning process. What it does do, however, is offer a sobering looking at predictable trajectories of innovation once an innovation is reported in the media.

A close analysis of 'roadmaps' like the 2016 version of the Gartner Hype Cycle of Emerging Technologies reveals that many of the topics could be classified as belonging to Artificial Intelligence (AI), yet this term does not appear at all in that version of the Cycle. Perhaps this is one of the features of AI as a field of research in that conventional understanding of what it actually is keeps changing. For example, much of the functionality we currently take for granted on our 'smart phones' such as voice recognition and location awareness, not to mention real-time video streaming, were regarded as aspects of AI not so long ago.

With some contrast in terminology, the *2017 Horizon Report* portrays AI as having a four to five-year time horizon for adoption within higher education (Adams Becker et al., 2017, p. 46). Such contrasting emphasis and terminology within the genre of reports that attempt to portray the future is commonplace, derived from and applied to a common understanding Another graphic perspective on the dynamics of change is provided by Bowles (2017), in which the notion of Learning 4.0 is introduced as a construct that aligns with concepts of an intersection between the 'fourth machine age' and the digital era commencing around 2006 and characterised by 'technology driven waves of continuous disruptive change'. Figure 12.3 represents this.

While hype and terminology can sometimes influence how we think about the future, and in our case the future of education, the fundamental characteristic of technological change is that it is relentless. For educators, engaging with technological innovation requires a willingness to explore both the benefits and dangers and to do that it is also necessary to recognise the trends as they are emerging.

As we reflect upon our own histories and our engagement with technology, and our own teaching and our observation of teaching and student learning, we cannot help but also be drawn into reflecting upon the impact of the past in providing pathways to the future. We offer an emerging snapshot of some trends:

- The recognition that Moore's Law continues to point to futures of technology in terms of costs associated with storage and processing power and the ongoing rush of improvements and efficiencies. Some commentators like Kurzweil (2005) have extrapolated the predictions much further—predictions that have influenced the establishment of institutions like Singularity University.
- The continued expansion of the connected world with development of the Internet of Things (IoT) which will likely bring numerous consequences for both formal and informal education. *What is meant by 'teaching' as learners become more*

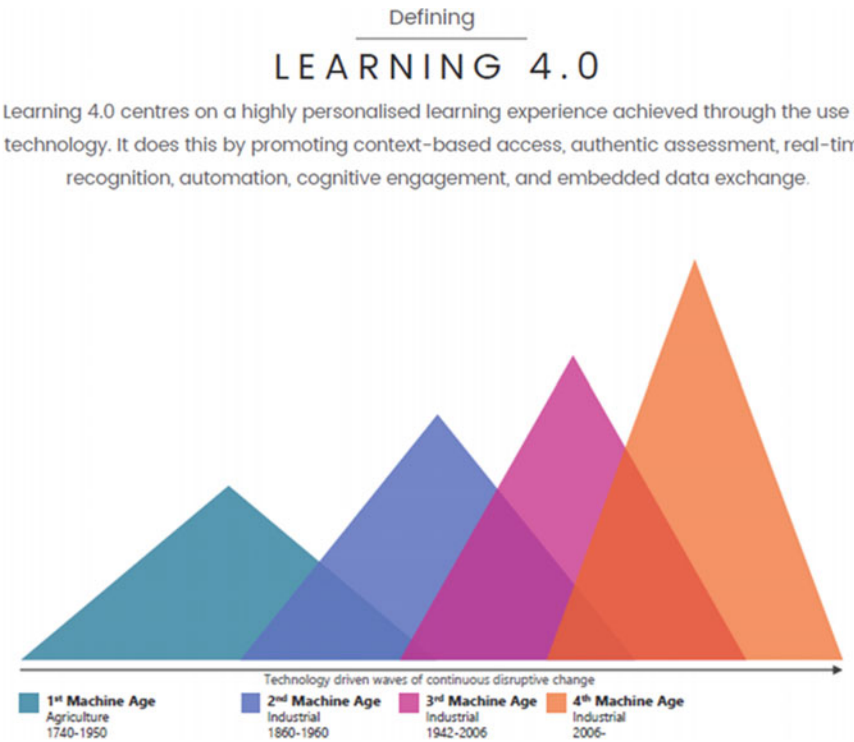

Fig. 12.3 Learning 4.0: Trends to Watch in 2017 (Bowles, 2017)

self-directed and personally and individually connected in their learning? As the IoT transforms the ways in which we access, are aware of, generate and share information based increasingly on an as-needed-basis, implications arise for data governance—tracking the origins and destinations of data becomes important for privacy and provenance reasons.

- The continued evolvement of human–computer interfaces. Technologies supporting augmented reality and virtual reality are already being mainstreamed and opening new dimensions to experience—and hence, the scope of our learning. A key question emerges: *where is the role for pedagogy with such experience-based technologies—shared with machines as well as people?*
- The emergence of a new era for technology standardisation in which AI is now enabling a range of new *smart learning environments* (Zhu, Yu, & Riezebos, 2016; Hwang, 2014; Koper, 2014). Such smart new learning systems potentially allow a shift of current learning technology and pedagogy, extending learning technology systems' architectures, particularly when coupled with shifts in how we view and construct learning. Learning management systems (LMSs) and their current pivotal role within education institutions, digital infrastructures are a product of these earlier architectures and pedagogy. Learning management systems tend to be

used as pre-constructed, linear and prescribed ‘learning experiences’. The use of such hardwired instructional design approaches as is typically in the use of LMSs will be challenged in the smart learning environments of the future.

- The monitoring of content of science fiction, because it is often grounded in real theory, provides insight into possible real futures. So, the kinds of interfaces portrayed in the *Minority Report* are really a potential. A HD retina quality fully stereo vision, stereo sound, immersive experience is not far-fetched. Taking a ‘trip’ to the Eiffel Tower or the London Museum is not so unbelievable. But also, such a vision of the future breaks away from the current status quo of innovations being seen as enhancements to learning management systems.

12.2.2 Pedagogical Change

Our discussion of the future of learning facilitated by digital technology so far has a technology focus. And yet, the interplay of pedagogy and technology cannot be ignored, let alone assumed to be natural (Lewin & Lundie, 2016; Ferguson et al., 2017; Sharples et al., 2016). Many writers profess that in formal education, pedagogy needs to drive the application of digital technology rather than simply finding an educational application of a particular technology (Hughes, 2005; Salomon, 2002). This is rarely the case, however, and the reasons for this are complex. In some contexts, while such a position is a natural one for educators to adopt, it is also the case that tinkering with technology in an exploratory way can and does drive innovation in teaching and learning.

People, teachers, and students, are central to processes of teaching and learning. People exist within social, cultural, experiential and historical contexts, which strongly influence how teachers teach and how students learn. The emergence of digital technology in people’s daily lives is relatively quickly absorbed into their practices, though even here there is a delay, often in finding a way to use technology and where it takes on a social imperative. However, this is not necessarily the case within education. The practices of teachers are constrained by their own histories, experiences and values; and students’ learning approaches too are influenced by their own experiences of learning and to some extent, where this is possible, their own learning styles (Gibson, 2001).

The ongoing revolution of technology adoption within education is no less a revolution of technology-enabled pedagogy when considered over time. The production of annual analysis such as *The Horizon Report* (Adams Becker et al., 2017) and *Innovating Pedagogy* (Ferguson et al., 2017; Sharples et al., 2016) demonstrate ample evidence for this. Thus, the use of technology by a teacher 40 years ago bears little resemblance to that which teachers use today, although, this can vary significantly across the globe. Teachers in economic prosperous communities have easy access to a wide range of technologies from both community infrastructure and personal devices. Teachers in less economic abled communities of some countries, however, still struggle even to get basic technology such as electricity and Internet access.

Teachers are also constrained in what they do by the systems and institutions in which they work including their individual schools. In some cases, curriculum can direct pedagogical approaches, and constraints of class size, packed curriculum and external requirements, such as national examinations, can have a restrictive impact on what a teacher is able to do.

Probably the greatest impediment to teachers adopting or adapting digital technologies for student learning is the significant inertia that exists in trying to bring about a cultural change, particularly changes in entrenched practices. And when we are talking about increased application of digital technology for learning, and for future learning, we are indeed talking about bringing about cultural change in the very nature of teaching and learning. A clear example is the shift from didactic teaching towards student-centred, self-regulated learning. This shift does not herald the demise of teachers; to the contrary, it calls for imaginative and appropriate responses in teaching practice.

Education is surely about a process to assure efficient, effective and relevant learning by the learner. So therefore, any discussion about the application of digital technology in education must have a primary focus on how the application of digital technology results in at least increased efficiencies, effectiveness and relevance. But there are other considerations as well. Systems and individual teachers also need to make teaching decisions influenced by access and equity, what motivates student engagement, and what knowledge and skills student (and the teacher) need to be able to use digital-enabled pedagogies.

To reiterate, the revolution in education is by no means just a revolution in the application of technology. There have been significant changes in education practice, based on research and changing theories of teaching and learning. Constructivism, drawing upon the theories of Piaget and Vygotsky, has taken a central stage over the past few decades in recognition of where learning actually takes place, that is, in the learner (Jones & Brader-Araje, 2002). Social constructivism further recognises the social contexts that we exist in, and typically learn in. With the advent of Web 2.0, digital technology supporting social constructivism pedagogies have become available, and now support many approaches to online distance education. While acknowledging the value of constructivism, Siemens (2004) and Downes (2014) have advanced a new 'theory of learning for the digital age' known as connectivism in which the power of connections made possible by networks plays a prominent role. Other theories of education that have a place now within our growing digital worlds include Complexity Theory (Snyder, 2013), which recognises the complexities of learning, puts the learner into a position of potential transformation. Complexity theory contrasts with positivist theorists and educators such as the proponents of direct instruction as a dominant pedagogy. Transformative Learning Theory (Davis, 2015) seeks to construct learning experiences which disorientated the learner into a paradigmatic transformation, new ways of understanding and new ways of viewing the world. Indeed, there are numerous emerging pedagogies that are focused on maximising the affordances of networked digital technologies (Ferguson et al., 2017; Sharples et al., 2016; Kalantzis & Cope, 2012), The development, expansion and growing dominance of the Internet in our daily lives is manifested in a variety of ways—as a tool of communication, a platform for knowledge construction and sharing and as a knowledge depository that has revolutionised the way we now access information and construct understanding. This has resulted in new 'Net-Aware Theories of Learning' and conceptions of 'new learning' (Anderson, 2016; Kalantzis & Cope, 2012). Such approaches might have foundations in more traditional approaches to education, such as information provision is a replication of some functions of what previously were done in libraries, but the consequences of the evolving digital infrastructure are more far-reaching. Not only are learners today able to access vast amounts of information, they can easily construct their own interpretations and understandings; and significantly for learning, they need to be able to discern the information that they access. Additionally, new literacy and research tools and knowledge is needed to be able to engage in learning via the Internet. A Heutagogical Theory of learning (Abraham & Komattil, 2017) within the digital age takes on significance as it becomes more obvious that learners need to be able to *learn how to learn* and navigate their own positions, and take active steps in what they learn, how they learn and when they learn. This is not to degrade the roles that teachers and education systems might play, but it does require a fundamental rethink of these roles.

Teachers today have an increased facilitation role whereby they provide a learning environment and scaffold student learning using digital technologies which was never previously available. However, current approaches to facilitation of learning are relatively recent. The industrial revolution ushered in industrialised education with the teacher as instructor, director and supervisor, as well as the provider of information. Such concepts of the centrality of the teacher remain today in the way that we organise education approaches and systems, and still dominate much of our pedagogical approaches. We have undertaken significant technological and social changes over the last 200 years, and it is the ever-increasing development and availability of digital technologies in the early twenty-first century that is transforming our lives. Yet, we little understand the transformative role of education let alone the transformation of education, and the roles of teachers in the ways that they apply digital technology that is occurring.

Most teachers today have a level of technology that they use in inter-professional practice and for their students' learning. However, the application of digital technologies in classrooms varies significantly, even in a developed country such as Australia. The situation becomes even more problematic when we tried to get teachers to think about what technology they might be using in the future. Foresight is always difficult, even when we are presented with visions of a future world based upon existing and emerging technologies, such as the possibilities of learning with mobile devices as a centrepiece of a student's learning environment. When we look at other technologies, the issues that Gartner's Hype Cycle for emerging technologies presents us are even more significant. Sometimes we do not know where we are going until we get there, and in some cases, this provides the interest and adventure that professional educators experience. However, as indicated above, the inertia that exists in the slow response and uptake of digital technology presents a challenge to not only existing educators, but also to teacher educators as they grapple to construct curriculum and learning experiences for future teachers to be able to cope with the technologies and appropriate pedagogy in support of students learning in a future world (Tondeur et al., 2016). Thus, we are grappling with the question of how we can better understand how teachers might be better prepared in responding to emerging technologies that will represent their changing roles and practices as teachers going towards 2030.

12.2.3 Nature and Role of Education, Direction of Change

The growth of scientific knowledge, and the advances in technology as its progeny, has had a far-reaching impact on how teachers teach and how learners learn, as explained in the earlier sections. Technology continues to evolve. And as we look towards our possible futures, we know that technology will continue to influence and transform pedagogical practices. While embracing technological advances and attempting to integrate those innovations in the educational process, one must not lose sight of a simple but fundamental question: why changes in teaching and learning occur. Change is usually needed and takes place when there is a gap between what is expected and what happens. Understanding what education does and what education is ultimately for lays the foundation for the identification of that gap and provides an overarching direction for further actions to fill the gap.

Education is commonly conceived as a process that can bring about changes. The experience of education, according to UNESCO, enables individuals to learn to know, to do, to be, and to live together (2005). Organised and intended educational practices help enrich our knowledge and improve our skills that are essential for different domains of life (Alan, Altman, & Roussel, 2008). More importantly, we may be able to acquire cognitive and meta-cognitive tools that facilitate future learning. Non-cognitive abilities developed through education, including personal traits, attitudes and motivations, are equally crucial for life (Pierre, Sanchez Puerta, Valerio, & Rajadel, 2014). Education is also a public good. It can go beyond the individual and drive changes at a collective level (Kumar & Ahmad, 2007). All the knowledge, skills, values and attitudes acquired through education prepare individuals to effectively participate in the economy and society (Biesta, 2015). Education, especially the qualification function of education, contributes to individual employment and employability and to economic development at the societal level. Education plays a role not only in economic growth, but also in social prosperity, and we can be fairly certain that this will continue in the future. For example, education equips people with knowledge and skills related to citizenship, which can have an impact on social and political engagement and on social cohesion (Heyneman, 2003). Additionally, we know that education drives innovations to help societies tackle pressing issues such as climate change and food security (Ahmed, Wang, Meng, & Khan, 2012). Education, fundamentally, is about the transformation of individuals and of the society that they live in, and such transformation will continue to be an important component of our education provision and also the outcome of effective education.

The description above around ‘what education does’ and ‘what education is for’ is surely general. Education does not take place in a vacuum. It brings changes to society and, at the same time, it is inevitably influenced by the political and social, economic contexts of society, and responds to the ever-changing situations and new characteristics of those contexts. Contexts matter, as they play a significant part in defining the role of education and shaping its practices. As society evolves, the set or sets of knowledge, skills, attitudes, values and competencies that are expected to acquire by individuals will change as well. Educational institutions and educators, accordingly, need to make adaptions in terms of what should be taught and how it is going to be taught.

So what does the world we are situated in look like and what will it possibly look like in the future? Education and its role can be examined and understood from a global and national perspective. On a global scale, development mainly underpinned by the revolutions in science and technology has brought tremendous benefits to people on the one hand, but has caused ‘what is arguably the largest set of crises that humans have ever faced’ (Noguchi, Guevara, Yorozu, 2015, p. 11), such as extreme urbanisation, climate change, environmental degradation and widening inequality. The international society and national governments, thus, have prioritised sustainable development as an alternative direction. Education is widely believed as a means for attaining the sustainable development goals (UNESCO, 2017). And yet, we do not see a cohesive and clear vision of how this will be achieved but rather, there is a sense of rambling along and tinkering with adjustments and having knee-jerk reactions.

The pressing challenges emerged in the broader contexts surely affect every one of us as well as the future generations. Today’s world, being fast changing and complex, requires constant learning that encompasses different contexts through one’s life span—lifelong and life-wide learning. One of the core features of lifelong learning is that the individuals take a much more proactive responsibility in orchestrating their learning. When planning for education and developing curriculum, we no longer exclusively focus on the knowledge and skills that can bring immediate benefits to the learners. Increasingly our curriculum and pedagogical approaches are reflecting a lifelong learning consideration based on concepts of just-in-time learning and meta-learning skills that enable the individual to know how to direct their learning. Some fundamental concepts remain. Education is primarily for the individual. People learn and that learning occurs in their mind and is transmitted through the psychomotor skills that they learn. But learning is not just focused on nor does it just affect the individual. The culmination of learning within communities has an impact on those communities and then on broader societies. As we look towards the future, we do not believe this will change. While the content, technology, pedagogy and other things might change in time fundamentally, the focus of and effect of education is on the individual.

12.3 Cases

The following two cases are presented as contrasting perspectives on shifts in pedagogy taking place because of digital technologies being adopted within higher education. They provide some indication of aspects of an education future, but they also show how our practices are still linked to the past.

12.3.1 Teaching University Teaching

Australia has a long history of distance education, particularly for rural and remote school students who have been served by correspondence lessons provided by 'travelling schools' since the early twentieth century. Radio broadcasts known as the *School of the Air* were established in 1951 and these continue today in the Alice Springs region of the Northern Territory. While distance education in Australia also has a significant history in higher education, it was not until the Worldwide Web was invented that transformation of the sector began to take place. This transformation has undergone much turbulence and has been characterised by an increasingly globalised and competitive market. A university education is now available to many more students, no longer an elite few. Both students and academics are increasingly on the move between institutions and most universities depend upon digital infrastructure in their service delivery. Where university teaching was once characterised by large lecture halls, it is increasingly shaped by the choices available as a consequence of online courses and the many forms of just-in-time learning now available. But, while students have increased flexibility, they also need to develop as self-regulated learners in which they have many more opportunities to direct their own learning.

In Australia, Charles Darwin University (CDU) is a regional university that has undergone rapid change since its forerunner, Northern Territory University, was founded in 1989. Prominent among these changes is its transition into delivering most of its courses online, which began shortly after the university was established in 2003. Such a move has clearly been in response to the competitive market conditions while also strategic in terms of expanding its reach. CDU's geographical location in Australia's far north makes it Australia's most regional university. Looking beyond the location and dispersed population of the Northern Territory, CDU is now positioned to engage effectively with the broader Asian region with a strong international outlook and regional focus. Building an adaptable and sustainable digital infrastructure to support this has been pivotal to this transformation and a key to future success.

In parallel to the history of CDU has been a history of Australian universities reappraising the function and credentialing of academic teaching in the wake of the digital revolution. Since Laurillard (1993) published her seminal work *Rethinking University Teaching*, which shone a spotlight on the transformative role of educational technology, Australian universities have progressively restructured so that university teaching not only has a more prominent function in university operations but is explicitly aligned to harnessing the affordances of digital technology for better student outcomes. For CDU, like many other universities, this has meant introducing a Graduate Certificate in University Teaching and Learning (GCUTL) which is designed to equip lecturing staff with requisite pedagogical perspectives and technological skills while promoting excellence in teaching.

Delivering online courses at CDU is not a 'one size fits all' approach with student enrolments in courses varying from single digit numbers to over 400. Moreover, some teaching is conducted entirely online, while some of it is a hybrid of face-to-face and online. It is also significant that up to 60 different nationalities are represented within current CDU enrolments. Such diversity within an overall context of trends student-centred learning and a wider services-based economy has brought significant challenges for teaching staff. As indicated earlier, this demands flexibility in pedagogical approach while also requiring heutagogical (self-determined learning) approaches as well.

While it is the case that social constructivism is a dominant guiding philosophy in education, it is also the case that many lecturers default to didactic teaching approaches, probably because it was how they were taught. This is revealed in the delivery of the GCUTL in which a range of other learning theories and pedagogical frameworks are considered. Examples include Connectivism (Downes, 2014; Siemens, 2004), TPACK (Koehler & Mishra, 2009), Community of Inquiry (Garrison, Anderson, & Archer, 2010), and other inquiry-based frameworks (Luckin, Clark, Avramides, Hunter, & Oliver, 2017; Manches, Bligh, & Luckin, 2012). The one thing that clearly connects all these approaches to teaching effectively in the digital age is turning away from traditional didactic pedagogy.

12.3.2 Teacher Professional Development in Indonesia

Introduction

Futures thinking, planning, and application of innovative approaches in education are relative concepts incorporating multiple dimensions. Relative, because situations differ from place to place, country to country and even locations within a country. What might be a futures scenario for one place may well be current practice in another. And yet, there are also lessons that can be learnt from the experiences of others as we think, plan and apply digital learning technologies. This case study details the development of and approach to online teachers' professional development in Indonesia. The technologies and pedagogy underpinning this approach are not new; however, for the Ministry of Education and Culture (MoEC) of Indonesia responsible for implementing this program, the technology and the pedagogy are new. The relevance of this case here is that it shows how international cross-fertilisation of ideas and practice is relevant, and how experiences built over time in one location can be transferred, modified and applied in another, even across cultural boundaries.

12.3.2.1 The Context

Since 2010, the Indonesian MoEC has been developing a new approach to teachers' professional development to further develop teachers' knowledge and skills. Addressing the quality of education in Indonesia has become a national imperative, emphasised by comparatively low PISA results for the nation, where out of the 72 countries reviewed Indonesia ranks 62nd (Pellini, 2016). Many teachers in Indonesia are still stuck in a teaching mode that is didactic, content delivery and assessment-driven focused (Suryaratri & Shaw, 2014; Deasyanti & Shaw, 2014). Towards the end of 2015, the Ministry embarked on a national programme to accelerate teachers' engagement in professional development programmes. The main thrust of this national programme was the development of a national systematic approach to teachers' professional development using an online modality as a centrepiece. The new programme was titled *Guru Pembeljar Daring* or Teacher–Learner online. There are over 3 million teachers in Indonesia and the Ministry's design required all teachers to undertake professional development each year.

12.3.2.2 The Pedagogy

The *Guru Pembeljar Daring* approach was based on work that had been done on the development of online professional development courses for school principals (Shaw, 2012). Some of pedagogical principles that guided the development of these courses included a competency-based training approach, learning to have a strong link and relationship to the work of teachers, learner-centred and activity-based and evidence-based authentic assessment. Most of the learning activities, and the design of the structure of the components of these courses were based on an Action Learning approach (Dilworth, Boshyk, Boshyk, & Dilworth, 2010), which requires the learner to apply their learning within their professional context, and reflect upon and actively engage in their learning (Fig. 12.4).

An instructional design model was also devised to assist in the curriculum and materials development within this program. This instructional design model emphasises the linkages between the target competencies, the learning outcomes, the assessment and then the sequence of learning activities (Fig. 12.5).

12.3.2.3 Digital Learning Based Pedagogy

A social constructivist and learning community approach was chosen as the overarching online pedagogy. Such pedagogy is premised upon the learners being active agents of their learning and constructing their own understanding within online learning communities. Such an approach is quite different from traditional professional development approaches in Indonesia where the instructor and the delivery of content dominate. Globally, a social constructivist and learning community approach

Fig. 12.4 Action learning

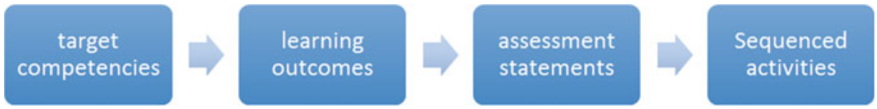

Fig. 12.5 Instructional design model

is the dominant digital learning pedagogy used within online contemporary higher education.

12.3.2.4 Online Learning Technologies

Moodle was chosen as the Learning Management System (LMS). Moodle is free, is widely available, and is supported by an active user base. It is a stable and sophisticated software suite with extensive features and many third-party add-ons. And most importantly, it is scalable with no limit to the user base and the number of courses that can be provided within an installation. Given that, up to 2000 courses had been identified for this online teachers' professional development programme, and that there are 3 million teachers in Indonesia, this is an essential feature for why it was chosen.

The design process for these courses required a restructure of existing learning materials and activities into a program based on 'Sessions'. These sessions comprised a series of structured elements that scaffold and direct learning.

12.3.2.5 Outcomes and Progress

By mid-2017, over 500 courses had been developed or redeveloped. And while the programme has undertaken several adjustments, the core features and principles have been retained. In parallel with this approach to teachers' professional development is an annual teachers' assessment examination. Teachers are directed into undertaking courses based on their results from these examinations. Some of the difficulties that are faced in implementing this programme include:

1. The challenges of bringing about culture change because of the different pedagogical approaches utilised and that online learning and teaching is a new concept in Indonesia.
2. Building capacity of course developers and designers, and other specialists required to support the digital technologies, has happened concurrently while developing courses. This is not ideal and inevitably there have been quality issues as a result.
3. The digital infrastructures and equipment available in Indonesia is inconsistent across the country. Internet access can be problematic, and yet, bandwidth, availability and reliability is improving rapidly.
4. Digital literacy in both teachers and learners generally start at low levels. However, the implementation of this programme has seen a significant and rapid improvement in digital literacy generally across the country, and this is translating into thinking and application of digital technology more broadly within Indonesian education.

The Indonesian education system took a proactive position in engaging in a 'future' approach to teachers' professional development, which has resulted in a significant realignment in tactics to teachers' professional development. The further development and evolution of this is now seen through the increased capacity and understanding of the potential of digital technologies in education that both practitioners and policymakers have.

12.4 Discussion and Conclusion

There are numerous issues that we see as important as we consider the shifting pedagogies within the context of digital disruption and transformation in the education sector and for education practice worldwide.

For over two decades, there has been a growing agenda focused on *21st Century Skills*, also referred to as *21st Century Competencies* (Bellanca & Brandt, 2011; Soland, Hamilton, & Stecher, 2013). Much of this is concerned with changing and complex demands on school-age learners brought about by innovations with digital technology and ubiquitous access to information. While the topic of 'digital literacy' has itself stimulated an extensive discourse, the challenges associated with engaging in the digital environment also involve challenges that are not traditionally classified in terms of challenges associated with 'skills' development—problems like the propagation of 'fake news', easy access to pornographic and violent content, cyberbullying, unwholesome interactions with others, social media addiction, radicalisation, scams and identity theft. So, *how do or should we adequately prepare our* *children so they can meet these challenges?* There are numerous perspectives within the relevant literature that respond to such a question and the following discussion represents an indicative sample.

'Digital Disruption' is a term now commonly used in contemporary discourse that speaks to the dynamics and impact of innovations with digital technology. University strategic plans and even job position descriptions use such terminology. In the *ASEAN ICT Masterplan 2020*, it is used with very positive connotations when articulating a vision that is 'Transformative—A progressive environment for the disruptive use of technology for ASEAN's social and economic benefits' (ASEAN, 2015, p. 10).

We recently initiated a comparative study of teachers who routinely use digital technologies. In this research, we focused on the skills, practices and attitudes of teachers in two remote locations—in Western China and the Northern Territory in Australia. In terms of the current situation, we found some differences between the two cohorts while also identifying common issues. In framing this study as a research project that considers readiness for a range of plausible futures, it also seems necessary that the discourse on 'skills' and 'competencies' needs to be complemented by perspectives that cultivate other personal qualities. For example, Gardner (2011) puts the case for '5 minds for the future':

- *The Disciplinary Mind*: the mastery of major schools of thought, including science, mathematics and history, and of at least one professional craft.
- *The Synthesising Mind*: the ability to integrate ideas from different disciplines or spheres into a coherent whole and to communicate that integration to others.
- *The Creating Mind*: the capacity to uncover and clarify new problems, questions and phenomena.
- *The Respectful Mind*: awareness of and appreciation for differences among human beings and human groups.
- *The Ethical Mind*: fulfilment of one's responsibilities as a worker and as a citizen.

Mason, Khan, and Smith (2016) provide a complementary perspective on this in conceiving of being 'discriminate' (or wise) as a much-needed foundation for education alongside literacy and numeracy where wisdom connects discernment of fact from fiction, ethical consideration, and informed decision-making.

And there are other considerations that we need to be mindful of as we consider the changes that are occurring in society, and the required response of education to these changes and the impact of this on individuals and communities. As societies evolve and adapt, so education systems and approaches also need to change and adapt. We can see this happening around us; as industry and work changes, as farms become increasingly mechanised, as robots take over the mundane, dangerous and repetitive tasks, as gadgets provide connectivity artificial intelligence. New approaches to education are evolving, both formal and non-formal. For example, the explosion in instructional and informative content through online resources such as YouTube, and the emergence and growth of MOOCS. Additionally, changes in society are bringing about a redirection of the focus of education and training. Increased affluence and leisure time have seen the emergence of a whole new range of needs and interest that are being addressed through new education and training movements.

12.4.1 The Lingering Questions

For us, the shift towards student-centred pedagogies continues within the context of ongoing global transformation and relentless innovation with technology. This shift raises essential questions that teachers and policymakers should consider when preparing for an ever-increasing range of possible futures that are driven or shaped by innovations in digital technology.

1. *How is society changing due to innovations with digital technology?*
2. *In what ways is digital technology currently being used in formal education settings?*
3. *What pedagogical practices have emerged as effective when using digital technology?*
4. *What drivers of change are shaping the reform or transformation of education?*
5. *What futures are plausible and which ones are likely?*
6. *What are the priority skills and competencies needed by teachers and learners for the future?*
7. *What is meant by 'teaching' as learners become more self-directed and connected in their learning?*
8. *How can we identify the right questions to ask?*

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Chapter 13
The Digital Teacher in a Mobile and Always-on World

Mohamed Ally

The old way of teaching will not survive in the digital and always-on era

13.1 Introduction

Society is becoming more ubiquitous where learners can learn and function from anywhere. The technology is getting smaller and more powerful allowing individuals to learn, work, socialize, access entertainment and conduct business from anywhere and at anytime. Libraries are being digitized and information formatted for access by mobile technology—'a library in everyone's pocket' (Ally & Needham, 2010). In the financial sector, customers now have the access to bank services using mobile technology—'in the pocket banking' (The Economist, 2007). The question is 'Where is education in the use of mobile technology to deliver flexible education?' Are we ready for 'education in the pocket and education everywhere' and if not, how long will it take to get there. This is the time for education to renew itself in the twenty-first century and in the Fourth Industrial Revolution to meet the needs of the present and new generations of learners and to provide 'education for all' regardless of learners'

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location or background (Alshahrani & Ally, 2017). This chapter will describe how the education system has to change to meet the needs of learners in a connected and always-on world.

There is a rapid growth of mobile technology in the world, especially in developing countries where mobile broadband subscriptions have surpassed fixed broadband subscriptions. Tablets and smartphones are outselling personal computers and are the tipping point for moving to mobile technology (Lee & Stewart, 2010). According to Naughton (2008), the technologies which triumph are those, which meet a major human need or satisfy a significant desire. The mobile phone represents a transition from a world in which telephones were attached to a wall, to a world where communication is always possible regardless of location and time (Naughton, 2008). Educators need to place a sense of urgency to design for delivery on digital technology so that learners can choose which technology to use for learning and obtaining support.

We are observing the domestication of mobile technologies. Mobile technologies are here to stay and will be used in all segments of education in the future (Ally, 2009; Gaskell & Mills, 2009). This will dramatically change the skills required by teachers to function in the digital era. According to mobile learning as an educational activity makes sense only when the technology in use is fully mobile and when the users of the technology are also mobile while they learn. Learning will move more and more outside of the classroom and into the learner's environments, both real and virtual, thus becoming more situated, personal, collaborative and lifelong (Naismith, Lonsdale, Vavoula, & Sharples, 2006). The learning space will be everywhere and learning will take place anytime. Rather than using the textbook to teach geometry lesson, a teacher in Ohio takes his students outdoors where they use smartphones to take photos of parallel lines, acute angles and other examples of geometric shapes (Puente, 2012). He also adapts the instruction to meet students' needs by sending students math problems on their mobile learning devices, varying the questions depending on each student's ability.

Learners use mobile devices to communicate, collaborate and access educational services for learning on the move and at individual convenience. Learners are ready to use mobile technology for learning but the question is 'are educators and teachers ready for mobile learning'. Corbeil and Valdes-Corbeil (2007) conducted a study where they asked students and faculty whether they are ready for mobile learning. Of the 107 students who responded, all students owned a smartphone or cell phone and 94% of the students said that they are ready for mobile learning; however, only 60% of faculty said that they are ready for mobile learning.

This chapter will describe how the education system has to change to meet the needs of learners in a connected and always-on world.

Is the Current Education System Still Relevant?

The current education system will not survive in the digital andlot of always-on world

The current education system is a complex system. The question is why is it so complex when learning is learner-centred and it is the learner who is doing the learning? If you think of a typical school today, common problems include high student absenteeism, vandalism, conflict between students, conflict between teachers and students, old infrastructure, closure because of extreme weather conditions, students and staff safety, and in some countries school security. The question is What do these have to do with learning? Why is education putting up with these problems when the learning materials can be designed and delivered to students using digital technology in a mobile world? In the current education system, students are educated in groups receiving the same instructions with quality control being done by giving tests at the end of a course. Students are given the same treatment with the assumption that they are homogenous at the start of a course. Digital teachers need to use the technology to design for individual learners rather than for a group of learners. With the advancement of technology, today why not take the 'school' to the learners rather than bring the learners to the 'school'. This will allow learners to learn at their own rate and in their own context with access to individual help as required. For practical hands-on training, education can work with businesses, industries and organizations to provide learning opportunities for students to develop their hands-on skills. The role of the teacher will change from presenter of information to a facilitator of learning using technology.

13.2 Education in a Mobile and Connected World

The use of digital technologies is changing the way we live and how we access education. One clear development is a blurring of our social, business, learning and educational lives as the pattern of our communication and interaction across time and space changes (Demsey, 2008). Countries around the world are starting to see that Internet access from anywhere and at anytime as a human right for citizens and have set goals to establish the infrastructure to allow access by all which will facilitate the use of mobile technology in education (BBC News, 2010). Gaskell and Mills (2009) list the different ways mobile technologies can be used in education. These include administration of learning, monitoring students' progress, providing learner support, interactive activities to promote higher level learning, delivery of learning materials, use of context-specific activities, workplace learning, just-in-time learning and reaching the disabled. Mobile technology also allows for expert-generated and learner-generated content that can be accessed by all (Adami, 2010; Ally, 2009). With social software, learners can share ideas, generate content and tutor each other.

Use of digital technology to reach students will benefit education by increasing enrollment and having a broader student population since students in different age groups can access course materials from anywhere and at anytime (Lowenthal, 2010). Mobile learning facilitates equal opportunity for all by allowing learning to be accessible across time zones and location and distance are not issues for the learner. Wireless mobile devices are small enough to be portable, which allow learners to use the device from any location to interact with other learners from anywhere, and at anytime to share information and expertise, complete a task or work collaboratively on a project. Learners can use the wireless capability of their mobile devices to access up to date and relevant learning materials from the web and to communicate with experts in the field that they are studying. Situated learning, which is the application of knowledge and skills in specific contexts, is facilitated, since learners can complete courses while working on the job or in their own space, and apply what they learn at the same time.

Digital technologies are becoming more embedded, ubiquitous and networked, with enhanced capabilities for rich social interactions, context awareness and Internet connectivity. Delivering education is not about the technology, it is about the learner. The learner is mobile and always-on and is at the centre of the learning and the technology allows the learner to learn in any context (MoLeNET, 2010). Vavoula and Sharples (2009) states that mobile learning is a social rather than technical phenomenon of people on the move constructing spontaneous learning contexts and advancing through everyday life by negotiating knowledge and meanings through interactions with settings, people and technology. Digital technology can be used to connect students from different parts of the world to create and share information with each other. Students can use the mobile telecommunication system to show the location they are in so that students from other parts of the world can learn about the areas in which other students are located. Botha, Vosloo, Kuner, & van der Berg (2009) conducted a study that examined global learning with students from different cultures using mobile technology. They found that the process of creation, sharing and negotiation provided an opportunity for students to foster relationships and to contextualize their lives to create shared understandings. The process used to create and share information between the different cultures resulted in the development of intercultural competencies and skills to communicate between cultures.

Studies have examined the use of mobile technology in the classroom and on campus (Cheng, Hwang, Wu, Shadiev, & Xie, 2010; Keengwe, Pearson, & Smart, 2009) but the use of mobile technologies have the greatest potential when they are used for remote learning. More studies should be conducted on the use of mobile technology in remote delivery. Ally and Stauffer (2008) completed a research project that allowed students to access their courses on mobile devices from anywhere and at any time. The majority of students responded that they agreed that the use of the mobile device to access the course materials was useful and provided both flexibility and convenience. Koszalka and Ntloedibe-Kuswani (2010) claimed that learning with mobile technology in the future will be conducted anywhere and anytime since the learner and technologies are both becoming mobile.

There is an increasing use of mobile technology in education around the world. In Canada, there are developments and research on the use of mobile technology in language training, workplace learning and reading by older adults (Ally, 2009; Ally, Balaji, Abdelbaki, & Cheng, 2017a, Ally, Samaka, & Robinson, 2017b; Ally & Stauffer, 2008; Ally, Woodburn, Tin, & Elliott, 2010). There are many major mobile learning projects in Europe, starting in the year 2000, that is contributing significantly to the expansion of mobile learning (Kukulska-Hulme, Sharples, Milrad, Arnedillo-Sánchez, & Vavoula, 2009; Naismith et al., 2006). Some of these projects include HandLeR, MOBILearn, Caerus, Mobile Learning Organizer, Myartspace, etc. (Naismith et al., 2006). Because of the flexibility that mobile learning provides, there is significant growth in enrolment at some educational institutions around the world.

I would move these two frames after introducing global perspectives or even later because these two cases are presented for making higher a quality of learning material. If they are here in the beginning, their role should be more connected and functional.

13.3 FRAME: Framework for the Rational Analysis of Mobile Education

To develop quality learning materials for mobile learning for learners on the move, Koole (2008) developed a framework (FRAME: Framework for the Rational Analysis of Mobile Education) for the mobile learning process that emphasized the interaction of the device, the learner and socialization (Fig. 13.1). According to Koole, effective mobile learning provides an enhanced cognitive environment in which learners can interact with their teachers, their course materials, their physical and virtual environments and each other. The process of mobile learning is itself defined and continuously reshaped by the interaction between the device (D), learner (L) and social (S) aspects. Mobile learning provides enhanced collaboration among learners, access to information and a deeper contextualization of learning. Also, effective mobile learning can empower learners by enabling them to better assess and select relevant information, redefine their goals and reconsider their understanding of concepts within a shifting and growing frame of reference (the information context).

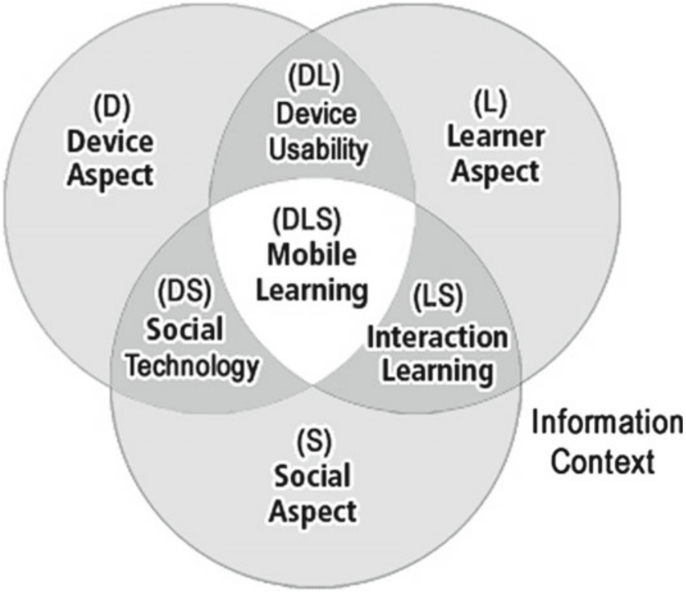

Fig. 13.1 Koole FRAME (reprinted with permission)

13.4 Comprehensive Framework for Designing Quality Digital Learning

Design of quality digital learning materials requires a team of experts to develop and implement the learning materials. Khan (2007, 2012) proposed a comprehensive framework for developing and implementing successful digital learning (Fig. 13.2). The framework is used to guide the design, development and implementation of digital learning. In the framework, emphasis is given on pedagogy, technology, interface design for the learner, evaluation, management, resource support, ethical considerations and institutional strategies. In order for digital learning to be successful, the infrastructure must be in place for learners to access the learning materials and for the teacher to provide support. For example, there are two strategies that are being used for mobile devices when implementing mobile learning. One option is to provide the mobile technologies to learners, which is efficient for the organization since the technology can be standardized across the organization. This will require support for a limited number of mobile technologies. A second option which is being adopted by some schools systems is Bring Your Own Device (BYOD). In this approach, learners bring their own mobile device to school to use for learning. This provides flexibility since learners can also take the device with them anywhere and anytime to learn. This approach is cost-effective since the educational organization does not have to provide the mobile technology; however, the organization must make sure that the learning materials can be accessed on a variety of mobile devices. Responsive design

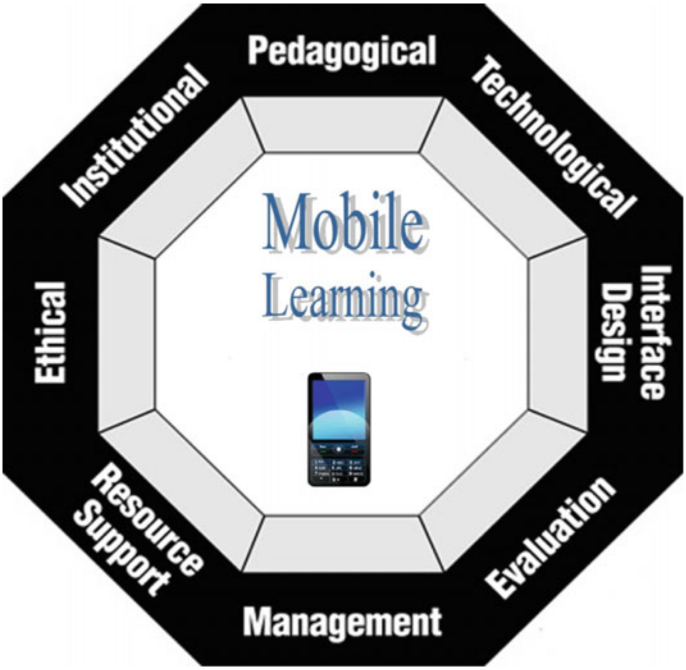

Fig. 13.2 Badrul Khan framework (reprinted with permission)

must be used which will allow for delivery on any mobile device. Also, the mobile learning system must have the intelligence to detect the mobile devices the learners are using and format the learning materials for different devices (Ally & Samaka, 2016).

13.5 Reaching Indigenous Peoples

One major advantage of using mobile technology is to reach learners in remote locations. There are approximately between 50 and 60 millions underserved indigenous people in Latin America who have limited or no access to formal education. Many of these people are nomads where they travel from one location to the next to make a living. An action research project was conducted to develop a mobile learning model to use mobile technologies to reach these underserved indigenous people (Kim, 2009). Results showed that the children were able to use the devices to learn and the parents used the devices occasionally to improve their vocabulary.

13.6 Examples of Mobile Learning Implementation Around the World

A major benefit of using mobile and emerging technologies in education is the ability to reach learners in hard to reach and remote areas. A recent project delivered education to high school students in a remote area where there is limited connectivity (Ally et al., 2017a, 2017b). Students were provided with tablets that have wireless capabilities which allowed them to access learning materials from a local server without having to connect to the internet. The teacher loaded the learning materials on the local server for students to access. This allowed the teacher to have control over what the students learn which is important for younger students. Results indicated that learners were comfortable using the tablets to learn and they increased their knowledge upon completion of the courses. Learners reported that they improved their computer skills which is important for the twenty-first century. Some of the visually impaired learners said the tablets allowed them to make the text larger which improved their reading.

Some Educational institutions are giving students mobile devices as standard resources required to complete an education. For example, Abilene Christian University gave iPods or iPhones to freshman students and the University of Texas at San Antonio and gave free iPod Touches to teachers who attended a technology training workshop (Hlodan, 2010). In addition, some governments of countries are giving students mobile devices or portable devices for learning. These initiatives are a good starting point for the transformation of education in the mobile technology age. However, some of these projects fail to prepare the teachers to function in the digital learning system (Farias, 2016). As a result, many of these projects are not successful.

MacDonald and Chiu (2011) tested the viability of augmenting an e-learning programme for the workplace using mobile content delivery; the multimedia mobile content delivered to learners via smartphones included text, audio and video, a multiple-choice quiz website, as well as links to streaming videos. While the mobile delivery of content was found to offer increased convenience and flexibility, video proved to be the most effective format of presenting mobile content, followed by audio and text.

Researchers and practitioners at a college are looking at augmenting English as a Second Language (ESL) and Communications classes by providing language practice outside the classroom walls using mobile devices (Palalas, 2010, 2011). Web-based mobile tasks were developed and offered to college students to support the development of English for Special Purposes listening skills. Students completed those tasks in the real-world environment and created multimedia artefacts using their own mobile devices. The cross-platform mobile learning solution proved to be effective and is being further developed to provide offline and online interactive options and hence accommodate students' data plans.

Grant et al. (2015) conducted a qualitative research study to describe the early uses of mobile computing devices in K–12 classrooms. Data was collected from teachers and the themes that emerged include (a) ownership and control impacted use of mobile computing devices; (b) administrators champion teachers' uses of mobile computing devices especially for student accountability; (c) teachers use devices to enhance their curricula and as motivation for their students; (d) teachers receive and seek out relevant professional development; and (e) technical issues were common, but support was available. These themes indicate the importance of teachers having the digital skills to function in the K–12 education.

Reeves, Gunter, and Lacey (2017) conducted a study to determine how integrating mobile devices into a Pre-Kindergarten curriculum using informal feedback from students affects students' academic achievement. The study used a 2-group, quasi-experimental design consisting of 28 students from 2 pre-K classrooms. The experimental group utilized iPads with guided instruction on emergent literacy and early math skills. The control group did not have access to iPads. Data was collected using the Florida VPK Assessment at the beginning and end of the study. Results of the ANCOVA revealed significantly higher Phonological Awareness and Mathematics measures for the iPad class, suggesting that integrating mobile learning in content-specific areas using informal student feedback effectively increases early childhood education students' academic achievement. Results indicated that mobile learning using informal feedback from students' to guide instruction significantly increased students' Phonological Awareness and Mathematics skills compared to a control group that did not receive targeted instruction using mobile technology. Based on the results of the study, teachers must have the skills to implement apps in the classroom for students to access and learn. Also, teachers need to be trained and spend the time and have the resources to use apps in teaching. Another important skill the teacher must have is to evaluate apps for quality and appropriate use for learning.

13.7 Mobile Technology in the Emerging Learning Landscape

The use of mobile technology in education provides the opportunity to use active learning strategies and for learners to learn in their own context which will result in higher level learning (Henriksen, Mishra, & Fisser, 2016). With mobile technology, a group of learners can assess content from electronic repositories or create their own content, validate the content and help each other regardless of locations. The learner-generated content can then be used by other learners (Traxler, 2009). Mobile learning benefits learners since they can use mobile devices to learn in their own learning community where situated learning, authentic learning, context aware learning, contingent learning, augmented reality mobile learning and personalized learning are encouraged (Traxler, 2010). Learning will move more and more outside of the classroom and into the learner's environments, both real and virtual, thus becoming more situated, personal, collaborative and lifelong (Naismith et al., 2006).

Mobile technology allows learners from different cultures to express themselves more readily compared to face to face (Wang, Shen, Novak, & Pan, 2009). Also, learners can use the technology to develop a community of learners where learners can tutor and help each other in the learning process resulting in high-level learning. Because of the information explosion, learners cannot continue to be consumers of information since information becomes obsolete in a short time in some disciplines such as computer science, business and engineering. Learners will become researchers and collaborators to find relevant information and to generate their own personal information. Use of mobile technology by learners will help the learners develop twenty-first-century skills required by learners when they join the workforce (Bestwick & Campbell, 2010). The digital teacher has to prepare the learner for the twenty-first-century workforce.

There are billions of mobile devices, tablet computers and portable computers being used by citizens around the world; however, a large majority of these citizens, especially those from developing countries, do not have access to learning materials. As the ‘digital divide’ decreases the ‘learning or education divide’ increases. The use of wireless mobile technology in remote locations and developing countries will improve students’ accessibility to learning materials, and therefore narrow the learning divide. Mobile learning programmes can be designed to allow educators to reach learners in remote locations and in developing countries. Included in mobile learning is supporting student learning through online collaboration and mentoring and building of learning communities. The use of mobile technology to deliver education allows for equal opportunity for all and to reach the nomadic and remote learner.

Most schools are located in urban areas and cater for learners on site where learners have to come to the school to learn. This model does not meet the needs of all learners, especially for those who live in remote locations, those who do not have the capability to go to school, and the nomadic learners who are on the move constantly. Nomadic learners are learners who are on the move from one location to the next in order to work, trade or to seek food and shelter. One way to reach these learners is the use of wireless mobile technology. The goal of nomadic learning is to enable a consistent learning experience for users anywhere in the world as they travel from one place to another (Ally, 2008b). According to Kleinrock (1996), the nomadic environment should be transparent to the user, regardless of location, the device and platform they are using, the available bandwidth and whether or not they are in motion at any given time. This is also true in a ubiquitous society where learners can be everywhere and access to learning materials should be transparent. The teacher has to function in a ubiquitous learning environment.

With digital learning technology the learner is the central focus of learning.

Gaskell and Mills (2009) identified areas that education has to address to implement mobile learning.

1. How to design materials for mobile technology using good pedagogy?
2. Who makes the decision to implement mobile learning?
3. Who provides the technology to learners—the institution or the learner?
4. The cost associated with implementing mobile learning.
5. Preparing staff for mobile learning implementation

The digital teacher has a major role to play for mobile learning to be successful. Learners already have the mobile technology so it will be easy to connect to the learners to provide them with educational materials and support. The school systems need to build the infrastructure so that they can connect to learners everywhere. This includes designing learning materials in the form of learning objects for mobile technology and placing the objects in electronic repositories for access from anywhere and at anytime. The trend is to use Open Education Resources (OERs), which will make education affordable for all. The communication capability of the technology will allow learners to connect with other learners around the world to prevent the feeling of isolation. The time has come for education to create a global learning object repository so that learners can access learning materials from anywhere and at anytime. This includes the technology to translate the learning materials from one language to the next to meet the needs of the different parts of the world since most of the learning resources on the internet are only available in English. According to the United Nations, access to basic education is a human right. With wireless mobile technology, governments, businesses, communities and educators can work together to facilitate universal access to learning materials regardless of location and culture.

13.8 Future of Mobile Technology in Education

In the future, digital technologies will look completely different from what they are today; hence, education must plan to deliver education to meet the new generations of students. According to a Futurelab report (Daanen & Facer, 2007), by 2020, digital technology will be embedded and distributed in most objects. Personal artefacts such as keys, clothes, shoes, notebook and newspaper will have devices embedded within them, which can communicate with each other (Daanen & Facer, 2007). This will make learning more ubiquitous and pervasive. The use of digital technology allows for cloud teaching where access to people, resources and information will float freely regardless of location (Sutch, 2010). Learners in different time zones and locations will be able to access tutors when needed. There will be a convergence of technology where the internet, phone, TV, networks will be accessed by one device rather than having multiple devices (Selwyn & Facer, 2007). The question is whether the education system and the teachers are ready for emerging digital technologies. The digital teacher must keep up with emerging technologies to take advantage of their capabilities to educate students.

13.9 Conclusion

In this fast-changing world, different stakeholders will have to work together to develop new models of education to cater for the new generations of learners who will be using digital technologies that do not exist as yet. There is a need to re-conceptualize education and make the shift from education to lifelong learning. The current model of education is outdated since it was developed before digital technology was introduced in education. The current model, based on classroom face-to-face delivery, is geared to educate a certain segment of the population. Also, teachers are being trained for the current model of education so they will continue using the model when they become teachers. Teacher training must be re-invented to prepare teachers for the technology-enhanced educational system. Governments around the world are investing millions of dollars to introduce digital technology in the current educational system. Governments should use the investments to reform schools for different delivery methods using digital technologies. The education system must examine the way learning materials are designed and delivered and take into consideration the needs and characteristics of current and new generations of students. For example, what is the ideal length of a course for technology delivery and what support is required in digital learning. The current generation of students uses 'always-on' technology where they need information and feedback 'now' rather than 'later'. Think back 20 years ago. Did you ever think that digital technologies, such as mobile devices, will have a large impact on education as it is today? What will be the situation in 2030? Is the teacher ready for the digital education revolution?

Digital learning is "green" learning since it reduces the use of paper and travel

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