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Seamless Learning in the Age of Mobile Connectivity

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Editors
Lung-Hsiang Wong
National Institute of Education
Nanyang Technological University
Singapore, Singapore

Marcelo Milrad
Linnaeus University
Växjö, Sweden

Marcus Specht
Open Universiteit
AT Heerlen, The Netherlands

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Foreword: Removing Seams by Linking and Blurring

How We Came Up with Seamless Learning

When I started to write the foreword for this book, I read again the first few sentences in the abstract of the paper that we, a group of international researchers, wrote (Chan et al. 2006):

> Over the next 10 years, we anticipate that personal, portable, wirelessly-networked technologies will become ubiquitous in the lives of learners—indeed, in many countries, this is already a reality. We see that ready-to-hand access creates the potential for a new phase in the evolution of technology-enhanced learning (TEL), characterized by a "seamless learning spaces" and marked by continuity of the learning experience across different scenarios (or environments) and emerging from the availability of one device or more per student ("one-to-one"). One-to-one TEL has the potential to "cross the chasm" from early adopters conducting isolated design studies to adoption-based research and widespread implementation….

I mulled over these sentences, thinking what each of them may mean by now, since the paper was published. Of course, the recent surging interest in *seamless learning* is a pleasant reward for us. Seamless learning, actually, has a long definition in the paper (p. 6):

> Seamless learning implies that a student can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using the personal device as a mediator. These scenarios include learning individually, with another student, a small group, or a large online community, with possible involvement of teachers, mentors, parents, librarians, workplace professionals, and members of other supportive communities, face-to-face or at a distance in places such as classroom, campus, home, workplace, zoo, park, and outdoors. Seamless learning space refers to the collection of the various learning scenarios supported by one-to-one technology. Exploration and investigation in the seamless learning space provides a potential to extend formal learning time, usually limited to the classroom, into informal learning time, to embrace opportunities for out-of-school learning driven by the personal interests of students, which may involve interacting with an online learning community, visiting museums, participating in community projects, or other venues.

When we used the word *space* in the term *seamless learning space*, we implied that *seamlessness* may be an overall description of all possible changes that technology may bring to education in the future. Many contributions in this book are, in some sense, oriented in this direction. I feel that it may be helpful and interesting if, in this foreword, I provide a historical account of the seamless learning notion from my personal (hence subjective) perspective. Then, following the revenue paved by Wong and Looi (2011), I will bring up possibilities of removing some particular seams by linking and blurring, hopefully inspiring some future work.

In March 2003, I hosted a small workshop with participants Pierre Dillenbourg (Switzerland), Ullrich Hoppe (Germany), Kinshuk (then New Zealand, now Canada), Marcelo Milrad (Sweden), and Jeremy Roschelle (USA). There were three questions that emerged, albeit vaguely, from this workshop: (1) How should we describe the forthcoming phenomenon: mobile, personal, and wirelessly connected devices being widely available to school-aged children and college students? (2) What change should we expect in education because of this phenomenon? (3) To respond to this phenomenon, could it be possible, for the first time in history, to have a global collaborative research endeavor? As we shall see below, the answers for these three questions subsequently came out in a series of exchanges, and they were, respectively, *one-to-one TEL*, *seamless learning*, and *G1:1 community*.

In that small workshop, Dillenbourg emphasized that pedagogies supported by technology, whether the learning is collaborative or individual, should be well integrated. Technology per se should be invisible so that the learning environment remains a natural place for human interaction. Ulrich addressed that learning can take place across different places (and hence different times) and among different number of people (from individuals to groups of different sizes). Roschelle shared their experiences in using PalmPilot in schools while Milrad and Kinshuk talked about the use of mobile devices in their innovative informal learning projects. As you can see, the concept of seamless learning—the answer for the aforementioned second question—was coming into view. But why did we use the word *seam*? That is another story, which I shall come back to later.

One year later, in March 2004, our university hosted the Second IEEE International Workshop in Wireless and Mobile Technologies in Education (WMTE). Prior and during the workshop, we arranged activities so that, together with the previous group of researchers, participants such as Nicolas Balacheff (France), John Cherniavsky (USA), Sherry Hsi (USA), Cathie Norris (USA), Miguel Nussbaum (Chile), Hiroaki Ogato (Japan), Mike Sharples (England), and Elliot Soloway (USA), as well as other researchers, joined the discussion. During our exchange, Soloway kept advocating the notion of *one-on-one*, which was modified to *one-to-one* by Sharples, and Roschelle and I later invented the symbol *1:1* as a shortened form of *one-to-one*. Consequently, the notion and the concept of *one-to-one* became our answer to the aforementioned first question—how do we describe the forthcoming pervasiveness of portable personal device for learning. Actually, advocating the *one-to-one* concept had an additional intention: conveying the message to the public and the policy makers that the arrival of the *one-to-one* era will cause a big change in education.

The collective effort of this informal group of researchers expanded and continued in the third consecutive year. In May 2005, 2 days before the main conference of Computer Supported Collaborative Learning (CSCL2005) held in Taipei City, Roschelle and his colleagues at Stanford Research International conducted a workshop at our university. In this workshop, more researchers, such as Roy Pea (USA) and Chee-Kit Looi (Singapore), joined. Roschelle and his colleagues guided our discussion using a *scenario-based planning* process to systematically explore possible futures from multiple perspectives (Roschelle et al. 2005). While we were certain that the advent of pervasiveness of personal learning devices owned by students would change the face of education, given the complexity of the educational system, we could not envision a single certain future. Nevertheless, we brainstormed ideas, applications, and concepts that might hold promise for reaching massive scale and predicted possible trajectories of future changes.

After these three workshops, more events continued, being held at different venues usually 1 or 2 days before international conferences. As can be seen from this series of events, researchers who were concerned about the 1:1 movement shared a vision of global collaboration. We intended to form an informal global research community—G1:1. And this intended global collaborative endeavor was the answer for the aforementioned third question. Unfortunately, for various reasons, the idea of G1:1 has not been realized.

In the autumn of 2005, feeling the need to conclude the series of exchanges in this period of time, I initiated writing a paper. When I tried to conceptualize our discussions from the first workshop in 2003, the word *seam* came into my mind because I had come across two seams: one I had encountered in my research and the other I had noticed for a long time in Taiwan's education. Like most researchers in our field, I have been striving to find ways to reduce or remove these two seams for years, yet they still, at least in Taiwan, remain.

Two Seams

Some background is needed to explain the first seam. My Ph.D. thesis proposed the concept of simulated learning companion (Chan and Baskin 1988, 1990) and developed a prototype system Chan 1991) in which a single computer simulated two agents: a student and a teacher. When I received my Ph.D. from the USA in 1989, my first project in Taiwan was to build a networked learning system that could allow students to learn with their *real* companions: their fellow classmates. Our small team wrote a learning program, featuring both collaboration and competition, for connected PCs in my lab. The first trial, conducted with students from my freshman class, involved connecting all the computers in the PC lab of our Electronic Engineering Department (Chan et al. 1992). This PC lab was our first 1:1 classroom. After a further series of research through the 1990s on such networked learning environments with both real and virtual companions (Chan and Chou 1995; Chan 1996), in the year 2000 I had an opportunity to lead a 4-year project with a budget of 14 million USD. Working on a project with such a scale, we intended to make an impact on the future of Taiwan's education. And for this purpose, two subprojects were instrumental: the Future Classroom subproject and the EduCity subproject.

For the Future Classroom subproject, which started in 2000, we established a number of 1:1 classrooms in several schools in Taipei City, using tablet PCs, which we called eSchoolBags. We designed and piloted 1:1 learning activities in these classrooms (Wang et al. 2004). We furthermore extended 1:1 learning activities from the classroom to the outdoors, permitting activities such as observing butterflies in campus or watching birds outside campus, with students bringing their mobile devices (Chang et al. 2003). Thus, what we meant by a Future Classroom at that time was a classroom that extended a physical classroom to the natural world. And this is an important feature of *mobile learning*.

For the EduCity subproject (Chan et al. 2001; Chang et al. 2004), we built an online learning society. By 2003, via a hierarchical structure, EduCity connected 1,700 schools (called EduTowns), 20,000 classrooms (called EduVillages), and 1.5 million students, teachers, and parents (called EduCitizens). Learning materials and educational software applications in EduCity are shared by teachers using Web 2.0 technology. Furthermore, any EduCitizen can run an online course in EduCity. One may ask why EduCity had such a large online learning community, with over 1.5 million users. When EduCity was launched in 2000, many computer teachers brought their classes to PC labs, where they participated in activities in EduCity. It was the fashion for many schools at that time to encourage students to become registered members of EduCity and to participate in online activities there. Additionally, many students and teachers were active in EduCity at home via their home computers because at that time, a majority of families in Taiwan already had computers at home that accessed the Internet. When the project came to an end by 2004, EduCity was transferred to the biggest telecommunication company in Taiwan for continuation of its operation.

When we were undertaking these two subprojects, I became aware of the first seam: the seam between the world of the online learning society (in our case, EduCity) and the world of the real classroom in schools (Chan 2010). These two worlds were not interacting. Why not? In most classrooms in Taiwan, a teacher could use his/her computer via a projector (now many classrooms are equipped with electronic whiteboards). Resources in EduCity could be accessed via the teacher's computer. Students, however, were unable to access computers in most classrooms. In this teacher-has and students-have-not situation, classroom activities remained teacher-centered—with the traditional ways of teaching continuing—not what we researchers wanted to see. The reason for this situation is that, in Taiwan, even today, there is no concept of *student computer*. This is unlike many schools in North America, which have several student computers in a classroom for students to use when they need. Apparently, 1:1 classrooms were the solution for eliminating the seam, and that was why we originated the 1:1 classroom campaign. Unfortunately, over these years, I realized that the prevalence of 1:1 classrooms would never become widespread, despite 1:1 personal computing already being the daily reality for teachers and students, unless we can link up with teachers for the sake of students' learning.

Ever since there were formal schools, another seam has existed: the seam between school and home. This seam has bred what I call *after-school schools*—

places where students go to after school—which are common in Taiwan and widespread throughout Greater China. Usually these schools provide multiple services. One service these after-school schools provide is to take care of students after school while parents are still at work, as nobody is at home to care for the children. In addition to this service, they help students finish their homework. Some after-school schools—called cram schools—offer special courses, for example, a special course for mathematics, claiming that such a course will significantly help children score better in school and in public examinations. The problem is that these after-school schools alienate and deteriorate the formal school system. For example, in some international assessments such as PIRLS and TIMMS (Mullis et al. 2011a, b), students in Taiwan, Hong Kong, and Singapore, compared to those from other countries, are at the top in reading and mathematics performances, but their motivations rank at the bottom. One of the reasons for this phenomenon of poor motivation is that students do a lot of drill and practice in these after-school schools, without consideration of their interest and motivation in the subject. Consequently, many students hate mathematics.

Removing Seams by Linking Up People

Apparently the prevalence of 1:1 classrooms will remove the first seam—the seam between the networked learning society and the real-world classroom. Now the question becomes: why will teachers accept and adopt 1:1 classrooms? Three conditions, I thought, need to be satisfied: learning must be more effective, learning must be more engaging, and teaching must be simpler and easier. In the past, researchers in our field conducted great quantities of research to prove that technology can really make learning more effective (in terms of learning performance) and more engaging (because most learning activities supported by technology are student-centered). We, however, have conducted little research to prove that technology can really lessen the teacher's load in the classroom so they can pay more attention to individual students, especially those slower students who demand more teacher attention. In the past, this was almost impossible to prove because it requires that everyone in the classroom has a computer at hand, so that expository video clips, simple practicing and grading, matching up students for collaboration, and logistic work, such as the distribution of information to students, can be taken care of on each student's computer. Thus, the advent of the 1:1 classroom allows us to satisfy the third condition—making teaching simpler and easier. Our experience, however, showed me that the three conditions are necessary, but not sufficient, unless we can link up teachers. Why? My story explains.

I once taught a teacher professional development course for in-service teachers of a school. An important component of the course was a pedagogy model of reading called sustained silent reading (Hunt 1970; Pilgreen 2000), which helps elementary students develop a reading habit. In particular, I emphasized the key to the success of this pedagogy: the teacher must act as a model reader for students (McCracken and McCracken 1978), that is, the teacher sits in front of the class and reads a book while the students read their own books. The teachers in my course were ordinary teachers, not inclined to use computers, yet it is very simple to model reading, and it does not require the use of a computer. Thus, all teachers should be able to do it. For the first 2 months in my course, teachers read books and discussed this way of reading. Then, with the support of the school administration team, who arranged time in the morning for reading, I asked all eight first grade teachers to start practicing it for 20 min every morning in their classes. Ten days passed. Then one morning, I quietly visited the school to ascertain how these teachers were doing. All eight classrooms of the first grade were located on the same floor of the building. So I softly walked through the corridor, observing how the teachers were conducting the model. To my great surprise, I found that most teachers were sitting at the back of the classroom, grading student homework; although some students were reading books, some were not; and the classrooms were noisy and chaotic. In one classroom, the teacher was in front, reading a book aloud to the class. In yet another classroom, the teacher was sitting in front of the class reading her book silently while students were reading books themselves.

After 2 months in my course, I had thought that these teachers would understand that sustained silent reading would be good for their students and would be ready to practice it in their classes. Apparently, this was not the case. I could not sleep that night.

The next day, I talked to the teacher who read the book in front of her class and told her that my research assistant would take a video on how she conducted her reading period. Then, in the next class of my course in the following week, I did not say anything what I saw in my visit. But I played the video. The teachers watched the video quietly, seeing their colleague sitting in front of her class, reading a book, while her students were reading silently and attentively. The other teachers, I guessed, must be wondering why the students of their colleague, in contrast with their own students, were so engaged in their reading. On several occasions after this class, I visited the first grade classrooms again. All teachers gradually became silent models of reading for their students.

It was interesting to note that although the first grade classes were all located on the same floor, the teachers did not know what the other teachers were doing, despite being just next door. Today, a teacher still works in an isolated world: a classroom surrounded by walls. The classroom walls, the artificial barriers, separate teachers.

A related phenomenon is that a majority of teachers will not truly believe that innovation—whatever innovation—will work if they do not see how their colleagues really practice it. It is only once they see a colleague practicing that they can take action. In short, they see, they believe, they act. Teachers need their peers to be models to learn from. That is what I mean by linking up teachers, *linking those who have adopted innovations with those who have not*. Playing a video in my class was an indirect way to link up teachers. In Taiwan, there is no lesson study practiced as in Japan and no master teacher showing their classes to their colleagues as in China, and classroom observation among teachers is not common. However, in professional development for teachers in Taiwan or elsewhere in the world, connecting teachers will change teachers and enable those changes to be sustained and scaled up and expanded, convincingly and effectively. Such a process of linking up with teachers may start with face-to-face interaction, be maintained through online interaction, and gradually become more and more sophisticated. With the three aforementioned conditions being satisfied and by ensuring that teachers are interconnected, the prevalence of 1:1 classrooms will soar, and the seam between the physical classroom world and the online learning society world will disappear.

Now, assuming that 1:1 classrooms become increasingly popular, the second seam—the seam between school and home that caused the abundance of after-school schools—will be significantly reduced. This is because, when students learn in 1:1 classrooms, their learning performance data will constantly be collected and analyzed via learning profiles. Such information will be constantly sent to their parents, causing parents, more frequently and intensively than before, to collaborate with teachers to improve learning of their children. In such a situation, tutors in after-school school would be forced to join the teacher-parent collaboration in helping children. Thus, linking up teachers and parents closely when 1:1 classrooms are on their way to prevalence will lessen the abnormality of formal education in Taiwan.

Removing Seams by Blurring

Digital technology gone through two revolutions: the network revolution in the 1990s and the mobile revolution in the 2000s. Because of the network revolution, an online learning society was created. Because of the mobile revolution, physically separated classrooms will become connected 1:1 classrooms. As time goes by, the seam between the virtual world of online learning society and the real world of classrooms, as well as the seam between school and home, will ultimately be removed. Now, what are the next technological revolutions? Moreover, what other seams did we human beings produce a long time ago that will be removed?

Obviously, in this decade, we are undergoing the game revolution, which encompasses digital games, intelligent toys, smart tangibles with entertaining elements, and others. When considered together with the previous revolutions, what the game revolution implies is that learning, playing, and working will be blurred. Life for our ancestors, in the history of human development, mainly consisted of playing and working, and learning was naturally embedded in playing and working. Indeed, if you investigate the essences of the processes of learning, playing, and working, you will not find much difference among them. It was we, the modern people, who distinguished between these three processes, and we thus created the seam between learning and playing, as well as the seam between learning and working. If we respect our inherent ability to play and work, inherited from our ancestors, then learning should be designed as a naturally embedded component of play and work. Taking advantage of our inherited ability to play and work, learning will be natural and engaging, effective, and achieving.

The keyword for blurring is "as," such as in "learning as playing" and "learning as working." Driven by the game revolution, learning as playing is now a popular field also called game-based learning. Furthermore, the game revolution will propel learning as working, or, more precisely, learning as professionalizing (Shaffer 2007). Inquiry-based learning is a pedagogy in which students learn as professionals do. A well-known example is learning science by following the same procedures that a scientist does in conducting scientific research. Note that some of our ancestors might be inclined to be scientists: they were curious about natural phenomenon and had aptitude for developing and testing their theories to explain what they observed. Similarly, learning writing as what a writer really does, learning speaking as what an anchor really does, learning music as what a musician really does, learning engineering as what an engineer really does, and many others—all these will be much more feasible, authentic, and sophisticated because of the game revolution.

Another technological revolution, the big data revolution (Mayer-Schönberger and Cukier 2013), enabled by cloud computing, will follow the game revolution in around 2020. With this revolution, removing the seam between learning and assessing by blurring the two will profoundly affect education. Learning is a natural process. Assessing, whether by oneself or with others, is, along with learning, also a natural process, because one can then, without delay, reflect and improve learning. Examinations, especially public examinations, however, are not a natural process, because they are for administrators, not for learners. The existence of examinations indicates that formative assessment alone is not reliable enough to be trusted by administrators. But this situation will change. With the big data revolution, we assess as we learn and we learn as we assess. Blurring learning and assessing in such a way, we shall no longer need examinations.

We may also interpret the blurring of learning and assessing in different ways. For example, learning as assessing may imply a kind of metacognition: when we are learning, we should be thinking critically about the learning tasks at hand and be aware of our own learning performance. Assessing as learning, on the other hand, may denote that, for enhancing learning, we should engage in more assessing activities. Whether it is learning as assessing or assessing as learning, big data technology will enable these two processes.

The blurring of the seam between human companion and virtual companion is particularly imaginative and interesting (especially to me). Why? There are three reasons. First, it directly challenges the Turing test, a test to see whether computer can demonstrate intelligent behavior as a human does, to the extent that a human person cannot distinguish whether the behavior is from computer or human. Second, it may become reality in 20 years because of big data revolution. Third, it was a dream in my Ph.D. work.

Before going further, let me first define *interaction bandwidth*. Interaction bandwidth refers to the amount of information one can receive while interacting with someone or something in real time. Now, we may consider several scenarios. First, in face-to-face interaction, one gets the largest interaction bandwidth, of course. Second, consider current video communication software, such as Skype or FaceTime; they are becoming commonplace. Video communication perhaps yields the second largest interaction bandwidth. Third, voice-to-voice interaction, via phones, both traditional and mobile, has perhaps the third largest interaction bandwidth. Fourth, consider 20 years ago when the only way to communicate synchronously on a network with another person was through typing text in a network application (advanced software at that time). Such line-editing to line-editing interaction had almost the minimal interaction bandwidth. Fifth, in 2015, PISA (the Programme for International Student Assessment) will conduct an assessment on collaborative problem solving. Students will interact with one or more simulated students in solving a problem collaboratively. In their implementation, icons representing simulated students may be used to communicate via text with the human student. This is still a line-editing to line-editing interaction; thus, the interaction bandwidth is still the same as in the previous scenario. But the main difference is that the human student interacts with simulated students, not human students. Sixth, actually, online games have long been utilizing virtual characters, and PISA just begins. The various forms of virtual characters in online games can be roughly classified into two categories: non-player character (NPC) and avatar. An NPC is a human-like character that interacts with the user during play. An avatar, which is also a human-like character, represents the user, because it is controlled by the user while the user is interacting online with other NPCs or avatars of other users.

As can be seen from the last scenario, if online games are designed for learning, then NPCs are actually virtual learning companions. With big data technology, we can imagine that there will be *smart* virtual learning companions interacting with a student. They are smart because they can tailor their interactions with the student for the benefit of the student's learning. Again, with big data technology, we can also imagine that when the student is trying to interact with an avatar of his/her peer student, the avatar is not the one being controlled by the peer but an autonomous avatar representing his/her peer. The last situation is particularly intriguing, as it implies you can either interact with your fellow peer who is currently online or his/her digital clone (autonomous avatar) if not online. The behavior of his/her digital clone is based on the analysis of the student's past learning data profile as well as the enormous learning databank of other students. What it means is that we are blurring real human companion interaction with virtual learning companion interaction. Are we removing seams between one's past and present and future? Is this good or not? This debate will continue in the rest of this century.

Summary

Evidenced by the work in this book, *seamlessness* has become an overall concept in describing what technological innovation and impact may bring to education. Here in the foreword I record the collective effort by a group of international researchers a decade ago: how the concepts of seamless learning and 1:1 TEL were developed. I also describe two seams—one was the result of the network revolution and the mobile revolution in the 1990s and the 2000s, and the other has existed since we had formal schools. To remove these two seams while developing 1:1 classrooms, I argue that the most effective way is to link up with people. Finally, I delineate the removal of some other seams by blurring, which will be propelled by the game revolution and the big data revolution in 2010 and 2020.

National Central University Tak-Wai Chan
Taiwan City, Taiwan

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Preface

Since the beginning of the last decade, the proliferation of mobile and ubiquitous technologies has opened up new opportunities for developing novel technology-enhanced learning approaches that are genuinely addressing the needs of nurturing new generations of citizens for the globalized society, digital lifestyles, and knowledge-based economics in the twenty-first century. At their keynote speeches delivered at IEEE International Workshop on Wireless and Mobile Technologies (WMTE) 2002 and International Conference on Intelligent Tutoring Systems (ITS) 2014, Cathleen Norris and Elliot Soloway put forward the notion of 1:1 (a ratio of at least one computing device for each student) and argued that the ownership and regular use of a personal computing device can change how we learn. Relevant studies then ensued, which had led to the exposition of the notion of mobile-assisted seamless learning in 2006, in a major international synthesis of 1:1, 24/7 technology-enhanced learning that involved 17 distinguished worldwide researchers from the learning sciences and technologies disciplines, including Tak-wai Chan, Jeremy Roschelle, Sherry Hsi, Kinshuk, Mike Sharples, Tom Brown, et al. The paper, "One-to-one technology-enhanced learning: An opportunity for global research collaboration", proposes seamless learning as a learning approach characterized by the continuity of the learning experience across a combination of locations, times, technologies, or social settings, (perhaps) with the personal mobile device as a mediator. The basic rationale is that it is not feasible to equip students and knowledge workers with all the skills and knowledge they need for lifelong learning solely through formal learning (or any one specific learning context). Henceforth, student learning should move beyond the acquisition of curriculum knowledge and be complemented with other approaches in order to develop the capacity to learn seamlessly.

Since then, there has been a flurry of subsequent relevant discussions within the mobile and ubiquitous learning research community. A significant number of academic papers generated by scholars from Asia, Australia, Europe, and North and Latin Americas expounded the notion with varied emphases and/or adopted seamless learning framework to inform their actual research studies. Nevertheless, despite promising research findings, the nature and the potential of seamless learning had yet to be fully explored or holistically characterized. It remained to be a loosely defined notion without any established learning model or theory until the end of the last decade when a handful of characterizing or ecological frameworks such as "10 Dimensions of Mobile-Assisted Seamless Learning" were developed and gradually adopted by researchers worldwide to inform the designs or analyses of new seamless learning environments. The recent modelling efforts have perhaps played a key role in renewing the interest in seamless learning within the mobile learning field. In the *Innovating Pedagogy Report* series published by The Open University, UK, seamless learning is being identified in two consecutive years (2012 and 2013) as one of the ten up-and-coming pedagogies that might transform education.

Notwithstanding that as a still evolving area of research and practice, there are many questions remaining unanswered and a critical appraisal of seamless learning is needed. For example, how can seamless learning be theorized from the psychological and cognitive development and sociocultural perspectives? Should the seams in learning always be blurred or bridged? How can mobile devices and ubiquitous/cloud computing platforms be brought together to support genuinely anytime, anywhere seamless learning? How can the advanced technological affordances inform researchers, teachers, and learners in facilitating or carrying out seamless learning processes? How can we shift learners' (and teachers') epistemological beliefs in order to create conducive conditions for nurturing their habits of mind and skills in/for seamless learning practice? What are the critical success factors and the challenges in translating and scaling up seamless learning practice in various educational contexts—K-12, tertiary institutions, adult and workplace learning, etc.?

This book aims to be a unique effort to consolidate interpretations, visions, and past research and practices in seamless learning from diversified perspectives rather than reiterating the current state of the arts of seamless learning or mobile learning. Learning technologists and learning scientists who have been explicitly researching on seamless learning, or who did not think they were studying seamless learning but have indeed accomplished some research work that resembles the spirit and the salient characteristics of the stated learning approach, were invited to contribute with their intellectual understandings and valuable experiences on this theme.

This book is divided into four sections, with several chapters in each one of those. Specifically, the chapter contributions came from all continents in the world (except Antarctica), thus offering a genuinely global perspective with regard to research and development in the field of seamless learning. The four parts are:

- Part I: Modeling and Theorizing Seamless Learning (6 chapters)
- Part II: Technology Enhanced Seamless Learning (6 chapters)
- Part III: Pedagogies and Application Domains of Seamless Learning (9 chapters)
- Part IV: Seamless Learning in Social Contexts (3 chapters)

Part I focuses on exploring the theoretical foundations, frameworks, and models of seamless learning. In Chap. 1, Lung-Hsiang Wong gives a historical account of the developments and evolution of mobile-assisted seamless learning (MSL) in the aspects of conceptual groundings, framework developments, methodological considerations, and technological advancements. This is followed by four chapters on the explications of "flow learning" and "connected learning" as two forms of seamless learning (Mike Sharples; Chap. 2), mobiles as cultural resources for both formal and informal learning (Norbert Pachler and Ben Bachmair; Chap. 3), the "niche" for MSL from an ecological perspective (Yanjie Song and Siu Cheung Kong; Chap. 4), and a self-regulated learning model for MSL (Li Sha; Chap. 5).

Part II introduces a diversified set of innovative technologies to enable, enhance, or even reshape seamless learning practices. In Chap. 6, David Metcalf, Max Jackson, and David Rogers reflect upon four case studies of MSL and identify context as a key attribute of seamless learning. The next three chapters offer three different concepts and designs of technologies leveraging on both context-aware and cloud computing for learners' ubiquitous access to multimodal learning resources, namely, Ambient Information Channels (Marcus Specht; Chap. 7), Learning Cells (Shenquan Yu and Xianmin Yang; Chap. 8), and SCROLL (Hiroaki Ogata, Noriko Uosaki, Mengmeng Li, Bin Hou, and Kousuke Mouri; Chap. 9), respectively. To round up this section, innovative seamless learning environments to support cross-contextual situated learning and collaborative learning are described by Gustavo Zurita and Nelson Baloian in Chap. 10 and Paul Birevu Muyinda, Godfrey Mayende, and Jonathan Kizito in Chap. 11, respectively.

As an indication of the versatility of seamless learning, Section C put together various pedagogical approaches to facilitate seamless learning and investigate how seamless learning can be applied to the learning of specific knowledge subject domains. In Chap. 12, Mike Tissenbaum and James D. Slotta report on a curriculum that engaged students as a knowledge community across contexts, which is concluded by proposing design principles for the roles of intelligent agents and data mining in supporting MSL. In Chap. 13, Howard Nicholas and Wan Ng discuss general ways of framing pedagogy (from the perspectives of context, nature of learning, and technological constellation) so that MSL occurs. The rest of the chapters are centering in seamless language learning (Agnes Kukulska-Hulme in Chap. 14 and Lung-Hsiang Wong, Ching Sing Chai, and Guat Poh Aw in Chap. 15), seamless learning processes that connect in-class learning and outdoor mobile trails (Gwo-Jen Hwang and Ju-Ling Shih in Chap. 16 and Hyo-Jeong So, Esther Tan, Yu Wei, and Xujuan Zhang in Chap. 17), digital storytelling in seamless learning setting (Susanna Nordmark and Marcelo Milrad in Chap. 18), mobile seamless training in the armed forces (Christian Glahn in Chap. 19), and pervasive gaming for pre-environmental behavior at the workplace (Marco Kalz, Dirk Börner, Stefaan Ternier, and Marcus Specht in Chap. 20). Finally, in Chap. 21, Chee-Kit Looi and Peter Seow share the Singapore experience of an in-depth seamless learning implementation and effective scaling up that may inform the field in the challenges and strategies to bridge the gap between seamless learning research and practice.

As seamless learning is arguably rooted in the sociocultural perspective of learning, Section D is a collection of chapters that are specifically dealing with the practice of such an approach in social contexts. In Chap. 22, Dan Kohen-Vacs and Miky Ronen outline an approach for supporting cross-contextual CSCL (computer-supported collaborative learning) scripts in mobile learning setting. Leon Yufeng Wu and Chen-Chung Liu present a seamless socio-technical environment that extends one-to-one collaborative learning activities with shared display groupware beyond their original classroom-based settings in Chap. 23. Chapter 24 sees Jari Laru and Sanna Järvelä putting forward an approach that meshes together seamless learning, self-regulation, and CSCL with the use of mobile social media.

This book is aimed to provide a good balance between theoretical and practical perspectives and that goes beyond a collection of reports on specific research projects. Readers would be spared from thick descriptions of research methods and findings. Instead, they can look forward to significant rise-above and food for thoughts that would inspire further advancements in the learning notion.

Singapore, Singapore — Lung-Hsiang Wong
Växjö, Sweden — Marcelo Milrad
Heerlen, The Netherlands — Marcus Specht

Contents

Part I Modeling and Theorizing Seamless Learning

1 **A Brief History of Mobile Seamless Learning** ... 3
Lung-Hsiang Wong

2 **Seamless Learning Despite Context** ... 41
Mike Sharples

3 **Framing Ubiquitous Mobility Educationally: Mobile Devices and Context-Aware Learning** ... 57
Ben Bachmair and Norbert Pachler

4 **Employing a Framework to Examine the "Niche" for Mobile-Assisted Seamless Learning from an Ecological Perspective** ... 75
Yanjie Song and Siu Cheung Kong

5 **Self-Regulation: A Critical Learner Characteristic for Seamless Learning** ... 91
Li Sha

6 **Reflections on Case Studies in Mobile Seamless Learning** ... 109
David Metcalf, Max Jackson, and David Rogers

Part II Technology Enhanced Seamless Learning

7 **Connecting Learning Contexts with Ambient Information Channels** ... 121
Marcus Specht

8 **A Resource Organization Model for Ubiquitous Learning in a Seamless Learning Space** ... 141
Shenquan Yu and Xianmin Yang

9 Supporting Seamless Learning Using Ubiquitous Learning Log System 159
Hiroaki Ogata, Noriko Uosaki, Mengmeng Li, Bin Hou, and Kousuke Mouri

10 Situated Learning Theory and Geo-collaboration for Seamless Learning 181
Gustavo Zurita and Nelson Baloian

11 Requirements for a Seamless Collaborative and Cooperative MLearning System 201
Paul Birevu Muyinda, Godfrey Mayende, and Jonathan Kizito

12 Scripting and Orchestration of Learning Across Contexts: A Role for Intelligent Agents and Data Mining 223
Mike Tissenbaum and James D. Slotta

Part III Pedagogies and Application Domains of Seamless Learning

13 Mobile Seamless Learning and Its Pedagogy 261
Howard Nicholas and Wan Ng

14 Language as a Bridge Connecting Formal and Informal Language Learning Through Mobile Devices 281
Agnes Kukulska-Hulme

15 What Seams Do We Remove in Learning a Language?–Towards a Seamless Language Learning Framework 295
Lung-Hsiang Wong, Ching Sing Chai, and Guat Poh Aw

16 Experiences of Using a Blended Mobile Learning Approach to Connect Classroom and In-Field Learning Activities in a Local Culture Course 319
Gwo-Jen Hwang and Ju-Ling Shih

17 What Makes the Design of Mobile Learning Trails Effective: A Retrospective Analysis 335
Hyo-Jeong So, Esther Tan, Yu Wei, and Xujuan Zhang

18 Tell Your Story About History: A Mobile Seamless Learning Approach to Support Mobile Digital Storytelling (mDS) 353
Susanna Nordmark and Marcelo Milrad

19 Challenges and Approaches to Seamless Learning in Security and Defense 377
Christian Glahn

20 Mindergie: A Pervasive Learning Game for Pro-environmental Behaviour at the Workplace 397
Marco Kalz, Dirk Börner, Stefaan Ternier, and Marcus Specht

21 Seamless Learning from Proof-of-Concept to Implementation and Scaling-Up: A Focus on Curriculum Design 419
Chee-Kit Looi and Peter Seow

Part IV Seamless Learning in Social Contexts

22 Fragmented yet Seamless: System Integration for Supporting Cross-Context CSCL Scripts 439
Dan Kohen-Vacs and Miky Ronen

23 Supporting Seamless Learning Across Individual, Collaborative, and Community-Based Learning in One-to-One Learning Age 453
Leon Yufeng Wu and Chen-Chung Liu

24 Integrated Use of Multiple Social Software Tools and Face-to-Face Activities to Support Self-Regulated Learning: A Case Study in a Higher Education Context 471
Jari Laru and Sanna Järvelä

Afterword 485

Recommended Reading List 493

Index 497

About the Editors and Authors

Editors

Lung-Hsiang Wong is a Senior Research Scientist of the Learning Sciences Lab., National Institute of Education, Nanyang Technological University, Singapore. His work involves seamless learning, mobile learning, computer-assisted language learning, computer-supported collaborative learning, and teachers' professional development. He is an Associate Editor of the *IEEE Transactions on Learning Technologies*. He has developed the characterization model of "10 Dimensions of Mobile-Assisted Seamless Learning" (10D-MSL) and co-written (as the first author) a scholarly book in Chinese, *Move, Language Learning – Exploring Seamless Language Learning*, to be published by Nanjing University Press.

Marcelo Milrad is a Full Professor of Media Technology at Linnaeus University, Sweden, and the Director of the Center for Learning and Knowledge Technologies (CeLeKT). His current research interests include the design of learning environments to support learning about complex domains, collaborative discovery learning, and the development of mobile and wireless applications to support collaborative learning. He was one of the 17 scholars who co-authored the seminal paper on seamless learning, namely, Chan et al. (2006).

Marcus Specht is a Full Professor for Advanced Learning Technologies at the Welten Institute at the Open Universiteit of the Netherlands and the Director of the Learning Innovation Labs. He is currently involved in several national and international research projects on competence-based lifelong learning, personalized information support, and contextualized and mobile learning. His research focus is on mobile and contextualized learning technologies, learning network services, and social and immersive media for learning.

Authors

Guat Poh Aw is an Associate Professor in Asian Languages and Cultures Academic Group, National Institute of Education, Nanyang Technological University, Singapore. For the past 10 years, she has been actively involved in local Chinese language teaching, including serving in Education Ministry of Singapore as a Chinese language consultant, leading many school-based action researches and helping schools to develop innovative school-based curricula. Three of her key research interests are the use of metacognitive strategies in teaching and learning Chinese, the Chinese teacher professional development based on constructivism, and seamless language learning.

Ben Bachmair was a Professor of pedagogy, media education, and instructional technology at the University of Kassel, Germany, until his retirement in 2008. His specialties include: mass communication and education, media and learning, media socialization and media reception, and media within the cultural development.

Nelson Baloian obtained the Civil Engineering degree in Computer Science in the year 1988 at the Universidad de Chile, in Santiago, Chile. Later he obtained his Ph.D. degree in Computer Science from the University of Duisburg in 1998. His main research topic has been computer-supported learning, especially in the field of collaborative learning and distance learning. Currently he is Professor at the Universidad de Chile and part-time visiting Professor at the University of Waseda, Tokyo, Japan. He has been also regularly a guest Professor at the University of Duisburg-Essen in Germany. He is the author of about 20 journal papers, 50 peer-reviewed conference papers, and 10 book chapters.

Dirk Börner is an Assistant Professor at the Welten Institute at the Open University of the Netherlands. With a background in computer science, he is conducting research on ubiquitous learning support. In particular he focuses on the utilization of ambient information presentation in combination with mobile technology to support learners in authentic situations.

Ching Sing Chai is an Associate Professor at the National Institute of Education, Nanyang Technological University. His research interest is in the field of teachers' beliefs, technological pedagogical content knowledge, and computer-supported collaborative learning. For the past decades, he has been actively involved in numerous funded research projects and published widely in educational technology.

Christian Glahn researches and develops mobile blended learning solutions for security and defense organizations at the ISN at the ETH Zürich, Switzerland. His interdisciplinary research focuses on context-sensitive mobile and web systems for self-organized learning and professionalization. He holds a Ph.D. in Educational Technologies and a M.Sc. in Media Education and is involved in technology-enhanced learning for over 14 years and studies mobile and contextual learning for more than 10 years. In 2004, He coined the concept of micro learning, and since then he contributed to several international research projects on technology-enhanced learning. He worked and studied in Austria, Germany, Greece, Switzerland, and the Netherlands.

Bin Hou received his Ph.D. degree from the Graduate School of Engineering, the University of Tokushima, Japan, in 2013. Currently he is working at CyberAgent, Inc., Japan. His research interests include computer-supported ubiquitous learning, mobile learning, and language learning.

Gwo-Jen Hwang is currently a Chair Professor at the National Taiwan University of Science and Technology. He also serves as the Associate Editor of *IEEE Transactions on Learning Technologies* and the Executive Editor of *International Journal of Mobile Learning and Organisation*. His research interests include mobile and ubiquitous learning, digital game-based learning, adaptive learning, and artificial intelligence in education. Owing to the good reputation in academic research and innovative inventions in e-learning, he received the annual most Outstanding Researcher Award from the National Science Council of Taiwan in the years 2007, 2010, and 2013.

Max Jackson is a Masters student in biotechnology at the University of Central Florida where he focuses his research on neural-machine interfacing. He is the President of the UCF Synthetic Biology Club and the Graduate President of the Central Florida Society for Neuroscience. Prior to graduate school, Max worked for a mobile-learning application development company. He enjoys reading the classics and philosophy literature in his free time.

Sanna Järvelä is a Professor in the field of learning and educational technology and the head of the Learning and Educational Technology Research Unit (LET) in the Department of Educational Sciences, University of Oulu, Finland. Her main research interests deal with learning processes in technology-enhanced learning, self-regulated learning, and computer-supported collaborative learning. Her current research projects deal with supporting twenty-first-century learning skills, especially socially shared regulation of learning, in higher education.

Marco Kalz is an Associate Professor at the Welten Institute at the Open University of the Netherlands. He is currently involved in several national and international research projects in the domain of technology-enhanced learning. His research focus is on the use of pervasive technologies for lifelong learning, personal learning environments, and new approaches for assessment and feedback.

Jonathan Kizito is a computer scientist specializing in Software and Systems Engineering. He is an Assistant Lecturer in the Department of Computer Science at Makerere University. He holds a Master of Science Degree in Computing Science

(Software and Systems Engineering) from the University of Groningen and a Bachelor of Science Degree in Computer Science and Mathematics from Makerere University. Jonathan's research interests are mLearning, ICT4D, and health informatics.

Siu Cheung Kong is Professor and Head of the Department of Mathematics and Information Technology (MIT), the Hong Kong Institute of Education. He is at present serving as the President of the Asia-Pacific Society for Computers in Education (APSCE). He is also currently serving as the Editor-in-Chief of the international journal *Research and Practice in Technology Enhanced Learning* (RPTEL). He is also the Convener of Theory and Practice of Pedagogical Design for Learning in Digital Classrooms International Research Network (IRN) under World Educational Research Association (WERA).

Agnes Kukulska-Hulme is a Professor of Learning Technology and Communication in the Institute of Educational Technology at The Open University. She is Past-President of the International Association for Mobile Learning and serves on the Editorial Board of several journals including the *International Journal of Mobile and Blended Learning*. She has been researching mobile learning since 2001, most recently as part of the European MASELTOV project on smart and personalized technologies for social inclusion and a British Council project on Mobile Pedagogy for English Language Teaching. Her original discipline background is in linguistics and language teaching.

Jari Laru is a university Lecturer (tenured) in the field of learning and educational technology. He has done his doctoral thesis "scaffolding learning activities with collaborative scripts and mobile devices" in the context of Doctoral Programme for Multidisciplinary Research on Learning Environments funded by the Academy of Finland and Ministry of Education. His main research interests deal with design for learning, emergent technologies in the education, and using mobile devices as cognitive tools.

Mengmeng Li received his Ph.D. degree from the Graduate School of Engineering, the University of Tokushima, Japan, in 2013. Currently he works at Rakuten, Inc., Tokyo, Japan. His research interests include mobile learning, context awareness, and personalization.

Chen-Chung Liu is a Professor at the Graduate Institute of Network Learning Technology, National Central University (NCU), Taiwan. He leads iLearn (Interactive Technology for Learning) lab, which aims to develop socio-technical environments for enhancing individual and collaborative learning.

Chee-Kit Looi is a Professor of Education in the National Institute of Education, Nanyang Technological University, Singapore. He was the Principal Investigator of various seamless learning research projects conducted in Singapore since 2008 and has published widely in this area. His research interests include seamless learning, collaborative learning, and teacher orchestration of learning. He is an Associate Editor of the *Journal of the Learning Sciences*.

Godfrey Mayende is an Educational Technology expert. He holds a Bachelor of Science (Computer Science and Mathematics), Master of Science in Engineering specializing in information systems (mLearning), and Postgraduate Diploma in Education (ICT). Currently, he is an Assistant Lecturer and Coordinator of ICT/ eLearning at the Department of Open and Distance Learning at Makerere University with over 10 years experience. He is an educational technology consultant in the public and private sector. Godfrey's research interests are in the areas of ODeL; social media as used for teaching, learning, and student support; and digital assessment.

David Metcalf is a Senior Researcher and the Director of Mixed Emerging Technology Integration Lab (METIL), Institute for Simulation and Training, University of Central Florida. As a researcher, analyst, and consultant, he has been a leader in the learning and development space for more than 15 years, developing over 500 online courses and multimillion dollar projects. He earned his Ph.D. in Information Systems from Nova Southeastern University. He keeps current by continuing to hold appointments at several universities, including Walden University's Knowledge and Learning Management doctoral program. He is a frequent speaker at major learning and development conferences around the world. His first book on mobile learning applications with emphasis on corporate uses has been in significant demand.

Kousuke Mouri received the MS degree from the Faculty of Engineering, the University of Tokushima, Japan, in 2014. He is currently a doctor student at the Graduate School of Information Science and Electrical Engineering, Kyushu University, Japan. His research interests include computer-supported ubiquitous and mobile learning, augmented reality, and network analysis for authentic learning.

Paul Birevu Muyinda specializes in eLearning/mLearning. He is a Senior Lecturer and Head of the Department of Open and Distance Learning at Makerere University, Uganda. He holds a Postgraduate Diploma in Education (ICT) and a Ph.D. in Information System (mLearning). Paul has recently edited a book for InTech Publishers on "distance education" and has led a number of research teams. He is currently a Principal Investigator in a Norad-funded project for *Leapfrogging Makerere University's 1st Generation Distance Education into 5th Generation Distance Education.* Paul's research interests are in the areas of ODeL, mLearning, ICT4E, and ICT4D.

Wan Ng is an Associate Professor in Technology-Enabled Learning and Teaching and Science Education at the University of New South Wales, Australia. Her research interest lies in the area of digital technology education that includes blended, online, and mobile learning. In her 12 years as an academic, Wan has written around 70 publications for an international audience, including a sole-authored book and a sole-edited book in technology education. She is currently under contract to co-edit and sole author two books by Routledge and Springer, respectively, for publication in 2015 in the areas of mobile learning and educators' professional learning.

Howard Nicholas is a Senior Lecturer in Language Education at La Trobe University (Australia) and a Visiting Professor of English Language Education at Paderborn University (Germany). His research interests include second language acquisition and plurilingualism, language policy, and multilingual education. His work in mobile learning contributed to his recently published book (with Donna Starks) *Language education and applied linguistics: Bridging the two fields* that was published by Routledge and elaborated "multiplicity" as a framework for understanding and working with plurilingual and multimodal communication.

Susanna Nordmark is a Doctoral Candidate in Media Technology at the Center for Learning and Knowledge Technologies (CeLeKT), Linnaeus University, Sweden. Her research focuses on the design and implementation of sustainable technology-enhanced learning (TEL) initiatives, and especially so on efforts scaffolding interdisciplinary seamless learning experiences through mobile digital storytelling (mDS). With her initial Ph.D. work for the EU project "CoCreat," she explored in what ways mobile technologies combined with storytelling, multimodality, and creative collaboration could support mobile learning in formal and informal contexts. Since then, she has conducted a series of mDS studies in cooperation with teachers, pupils, and representatives from cultural heritage institutions, both in Sweden and abroad.

Hiroaki Ogata is currently a Full Professor at the Faculty of Arts and Science at Kyushu University in Japan. His research interests include computer-supported ubiquitous and mobile learning and computer-supported collaborative learning. He received several best paper awards such as WebNet1999, CollabTech2008, mLearn2009, and ICCE2010. He is an Associate Editor for *IEEE Transactions on Learning Technologies*, RPTEL, and IJMLO, and he is also an editorial board member of IJCSCL and SLE. He is a member of ACM, IPSJ, IEICE, JSET, and JSiSE and a senior member of IEEE.

Norbert Pachler is a Professor of Education. He is the founder and convenor of the London Mobile Learning Group (www.londonmobilelearning.net). His research interests are in the fields of technology-enhanced learning with a particular emphasis on mobile learning and e-learning, teacher education and development, and foreign language education.

David Rogers is the Chief Technology Officer of Mobilegov who heads the company's development lab in Orlando, Florida. He also serves as a research associate at the Institute for Simulation and Training at the University of Central Florida (UCF), where he earned a Ph.D. in the Text and Technology program. His dissertation research focused on the use of mobile learning in emerging markets. His area of research at UCF is focused on mobile software development for distributed service delivery, informatics, and humanitarian and disaster response missions. He develops learning and performance support applications in support of the federal government, nonprofit organizations, universities, the Department of Defense, and various industry partners.

Peter Seow is a Research Associate in the National Institute of Education, Nanyang Technological University, Singapore. He has worked on seamless learning research since 2008. He is currently a final-year Ph.D. student studying Singapore teachers' experiences in implementing 1:1 technologies in the classroom. His research interests include learning with mobile technologies, supporting teaching and learning through 1:1 technologies, and studying how schools scale and sustain innovations.

Li Sha is a postdoctoral fellow at the Learning Research and Development Center (LRDC), University of Pittsburgh. He obtained his Ph.D. in Educational Psychology from Simon Fraser University, Canada, and worked as researcher at the University of Hong Kong and the National Institute of Education in Singapore. His main research interests are in exploring students' motivation, metacognition, emotion, and behaviors in both face-to-face and technology-enhanced self-regulated learning and collaborative learning.

Mike Sharples is a Professor of Educational Technology in the Institute of Educational Technology at The Open University, UK. He also has a post as Academic Lead for the FutureLearn company. His research involves human-centered design of new technologies and environments for learning. He inaugurated the mLearn conference series and was Founding President of the International Association for Mobile Learning. He is Associate Editor-in-Chief of *IEEE Transactions on Learning Technologies*. He is author of over 300 papers in the areas of educational technology, science education, human-centered design of personal technologies, artificial intelligence, and cognitive science.

Ju-Ling Shih is a Professor of the Department of Information and Learning Technology in National University of Tainan, Taiwan. She earned her Ed.D. in Communication and Education from Teachers College, Columbia University. Her research interests include instructional design and qualitative research in digital learning, digital games, mobile learning, and technology-mediated education in various levels and fields. Her publications can be seen in academic journals such as *Educational Technology and Society*, *Computers & Education*, and *British Journal of Educational Technology*, among others. She received the 2012 Ta-You Wu Memorial Award and 2011–2013 Excellent Young Scholars Project from National Science Committee, Taiwan.

James D. Slotta is an Associate Professor of education at The University of Toronto, where he holds the Canada Research Chair in Education and Technology. Since 2005, he has directed the ENCORE lab (http://encorelab.org)—a team of students, designers, and developers who investigate new models of collaborative and collective inquiry. Our studies are situated in smart classrooms and other environments, featuring user-contributed content, aggregated and emergent forms of knowledge, and a variety of scaffolds for the orchestration of individual, small group, and whole class activities. Current research is concerned with collective epistemology, immersive simulations, collaborative knowledge building, learning across contexts, and tangible and embodied forms of learning.

Hyo-Jeong So is an Associate Professor in the Department of Creative IT Engineering at Pohang University of Science and Technology (POSTECH), Korea. Previously, she was with the Learning Sciences and Technologies Academic Group of the National Institute of Education, Nanyang Technological University in Singapore. She received her Ph.D. from Instructional Systems Technology, Indiana University. Her research interests include computer-supported collaborative learning (CSCL), mobile learning, and human-computer interaction (HCI). Since 2005, she has headed several research projects on emerging technology and media, including the "FutureSchools@Singapore" project supported by the National Research Foundation, Singapore. She is current chair of the Classroom, Ubiquitous and Mobile Technologies Enhanced Learning (CUMTEL) SIG, the Asia-Pacific Society for Computers in Education (APSCE).

Yanjie Song is a Assistant Professor at the Department of Mathematics and Information Technology, Hong Kong Institute of Education. She is currently researching on mobile technology-enhanced inquiry-based learning, personalized learning, and collaborative learning both in school and higher education. She is also interested in professional development supported by digital technologies and research methodological issues in mobile technology-supported learning environments. She has published a number of peer-reviewed papers on mobile technology-enhanced learning and teaching and professional development in SSCI journals.

Esther Tan is a doctoral student at the Munich Center of the Learning Sciences (MCLS), Ludwig-Maximilians-Universität, München (Germany). She earned a masters' degree in Intercultural Education at Berlin Freie Universität. Her research interests include in situ knowledge building and teacher agency and student autonomy in future learning environments. Her dissertation work investigates the use of classroom scripts to scaffold regulative processes in collaborative inquiry learning in both formal and informal learning contexts. She headed the IT department at Shanghai Singapore International School, Shanghai; served as an education officer in the Educational Technology Division, Ministry of Education, Singapore; and worked as a researcher on the Singapore Future School Project at the Learning Sciences Lab, National Institute of Education, Singapore.

Stefaan Ternier is a researcher at the Welten Institute of the Open University of the Netherlands. His interests are in mobile learning and learning object repositories and MOOCs. He applies this research in several national and international research projects in the domain of technology-enhanced learning.

Mike Tissenbaum is a Ph.D. candidate in Curriculum Teaching and Learning (CTL) department at the Ontario Institute for Studies in Education (OISE), the University of Toronto. His research explores how smart classrooms (environments in which the teachers and students are connected in real time through embedded, tangible, and wireless technologies) can support students and teachers to engage as a knowledge community in sustained scientific inquiry. His research also explores the roles intelligent software agents, data mining, and ambient and aggregated displays can play in supporting class activities and emergent class knowledge. A central part of this work has been the design and development of a sophisticated open-source technology infrastructure (S3), which facilitates the orchestration of collaborative curricula within and across multiple learning contexts.

Noriko Uosaki received the Ph.D. degree from the Graduate School of Engineering, the University of Tokushima in 2013. Currently, she is an Associated Professor at the Center for International Exchange and Exchange, Osaka University, Osaka, Japan. Her research interests include MALL (mobile-assisted language learning), seamless learning, CALL (computer-assisted language learning), computer-supported ubiquitous and mobile learning, CSCL (computer-supported collaborative learning), and TESL (Teaching English as a second language).

Yu Wei is currently a doctoral student at the Welten Institute at Open University of the Netherlands, with the focus on knowledge building and learning analytics, while working as a Research Assistant at the National Institute of Education, Singapore. Since receiving her masters' degree in knowledge management from Nanyang Technological University in 2011, she has been applying the knowledge and skills of data mining into educational research. Previously, she worked as a Research Assistant of the IDM Future School Project, Mobile Learning Activities to Foster Critical Thinking Skills and In-situ Knowledge Building in Integrated Humanities, which grounded her further studies in learning sciences and technologies.

Leon Yufeng Wu is currently a postdoc researcher at Science Education Center, National Taiwan Normal University. His research interest includes educational technology, online learning, science education, and scientific communication.

Xianmin Yang is an Associate Professor at the Institute of Education at Jiangsu Normal University in China. He also serves as the deputy director of Jiangsu Educational Informationization Engineering Research Center. His main research interests are technology-enhanced learning, mobile and ubiquitous learning, and smart education. He has been involved in several educational research projects and software engineering projects, publishing 30 academic papers indexed by SSCI, EI, and CSSCI (Chinese Social Sciences Citation Index). As the system architect, he developed two large-scale online learning systems. Meanwhile he participated in writing some important Educational Informationization Plans at the national or provincial level.

Shenquan Yu is a Professor and Dean of the School of Educational Technology at Beijing Normal University in China. He also serves as the Director of the Joint Laboratory for Mobile Learning established by the Ministry of Education and China Mobile Communications Corporation. He was funded by the National Program for New Century Excellent Talents in 2008. He is a consulting expert of the 12th Five-Year Informationization Plan of Chinese Academy of Science and expert committee member of the Ten-Year National Educational Technology Plan. His main research interests include mobile and ubiquitous learning, e-learning platforms, and theory and practice of regional e-learning.

Xujuan Zhang received her Master of Arts in Linguistics from the Chinese University of Hong Kong. She is now a Research Assistant at the Learning Sciences Laboratory, National Institute of Education, Nanyang Technological University, Singapore. Her research interests include computer-assisted language learning, mobile and seamless learning, computer-supported collaborative learning, and in-service teachers' professional development.

Gustavo Zurita received his Ph.D. in Civil Engineering, with a Computer Science major, from Catholic University of Chile. Currently he is an Associate Professor at the Department of Management Control and Information Systems of the Faculty of Economics and Business of the Universidad de Chile. His main research topics are computer-supported mobile collaborative learning, collaborative knowledge construction, and geo-collaboration. He is an author of about 50 conference articles and more than 20 ISI-indexed journal articles. Some of his journal articles are well-cited in the mobile learning field worldwide.

Chapter Reviewers

Inmaculada Arnedillo-Sánchez, Trinity College Dublin, Ireland
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Gustavo Zurita, University of Chile, Chile

Part I
Modeling and Theorizing Seamless Learning

Chapter 1
A Brief History of Mobile Seamless Learning

Lung-Hsiang Wong

Abstract This chapter of the book *Seamless Learning in the Age of Connectivity* centers on a critical analysis of the brief history of mobile-assisted seamless learning (MSL). The intention is to qualitatively outline and trace the evolution of MSL in the following aspects: (1) the (re-)scoping of seamless learning, (2) the conceptual groundings, and (3) the MSL-specific theoretical, characterization, ecological, design, methodological, and technological frameworks being developed. Rise-above discussions on the trends will then ensue in order to provide synoptic picture of how this line of studies have been evolving and advancing over the time. Through the analysis, it is further affirmative that seamless learning is much more than a special form of any other learning method. It is indeed a learning approach at its own right and with its own niche – with "*bridging* of cross-space learning efforts" as the defining feature.

The Two Lives of Seamless Learning

Seamless learning has two lives – one is in the field of higher education studies and another in technology-enhanced learning (TEL), particularly mobile and ubiquitous learning (m-learning and u-learning). The two "lives" were "born" more than a decade apart – in the early 1990s and mid-2000s, flourished by the seminal papers of Kuh (1996) and Chan et al. (2006), respectively. Nevertheless, despite bearing an identical name, the two "lives" have barely been "interacting" with each other (i.e., almost no cross-citation) until 2011.

The First Life: Reforming the Higher Education

The first life of seamless learning began with higher education scholars and leaders questioning of the gap between the roles of faculty and student affairs professionals (Bloland et al. 1994), reflecting two perceived domains of student life – in the classroom

L.-H. Wong (✉)
National Institute of Education, Nanyang Technological University,
Nanyang Walk, 637616 Singapore, Singapore
e-mail: lhwong.acad@gmail.com

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and out of the classroom (Kezar 2003). This functional and organizational dualism continues to be in conflict with holistic visions of how students learn and develop (Terezini et al. 1996). As a result, scholars in the stated field began to reexamine the need for integration of these roles and advocated a change in the culture of learning from separatist to seamless (e.g., American College Personnel Association 1994; Knefelkamp 1991) orientation. The new notion resonates with Dewey's philosophy of continuity, which "is based on a belief that people, as holistic beings, learn best by engaging mind, body, spirit, experience, and knowledge" (Kezar and Rhoads 2001, p. 162). To concretize this notion, American College Personnel Association (1994) stressed the importance of linking students' in-class and out-of-class (though still in-campus) experiences to create seamless learning and academic success.

Picking up from the earlier literature, Kuh (1996) further elaborated the notion by extending it to involve off-campus experiences:

> The word seamless suggests that what was once believed to be separate, distinct parts (e.g., in-class and out-of-class, academic and nonacademic; curricular and co-curricular, or on-campus and off-campus experiences) are now of one piece, bound together so as to appear whole or continuous. In seamless learning environments, students are encouraged to take advantage of learning resources that exist both inside and outside of the classroom. Students are asked to use their life experiences to make meaning of material introduced in classes. (p. 136)

Kuh (1996) proposed a set of policy-level principles with the aim of fostering a culture of seamless learning within colleges. Although these principles are advocates of systemic reforms in nature (i.e., cross-functional dialogue and collaboration among college departments), it is meant to be a top-down approach with the ultimate aim of transforming students' learning method and in-campus lifestyle.

Focusing on integrating formal and informal learning, Kuh's (1996) exposition stimulated further discussions (e.g., Bell 2000; Kezar and Rhoads 2001; Seifert et al. 2008) and inspired further relevant studies (e.g., Kezar 2003; Smith and Northrop 1998), though with various emphases. Other researchers added the dimension of learning community (e.g., MacGregor et al. 2001; Tinto 1998) and the intertwining of individual and collaborative learning (e.g., Kazmer 2005; Skop 2008) into the notion.

The early literature on seamless learning remains centered on systemic-level reforms in the US higher-education sector and received little attention from other sectors or in the context of other national systems. Furthermore, technological support of learning played no significant role in this discussion. However, on the second point, this is not to say that there was absolutely no literature on "TEL in seamless learning settings." For example, Bonner et al. (1995) characterized their model of "distributed multimedia university" as a seamless learning setting, where college students may extract relevant multimedia learning resources anytime, anywhere to address their learning or problem-solving needs. A concrete seamless learning scenario was described in another paper published by the same team (Bonner and Basavaraj 1995): In a commerce course, students collaboratively solve real-life or mock-up business problem across time and space, via the network. As these papers were published during the early stage of the commercialization of the Internet services while mobile phones still looked and weighed like bricks (and yet to turn "smart"), the authors would obviously not associate their vision with m/u-learning. Nevertheless, the team had somewhat offered a preliminary sketch of technology-mediated seamless learning. As predicted by the team, "seamless learning could be well with us by the year 2010." (Bonner et al. 1995, p. 3).

Elsewhere, in explicating their new conceptualization of service learning, Kezar and Rhoads (2001) discussed about how (originally non-ICT-based) seamless learning can be extended to MUDs (multi-user dungeon games), online chats, hostels, stadiums, and social service activities – which implies the bridging of physical and digital realities. Furthermore, Taylor (2004) advocated using Internet to connect school and home learning.

The Second Life: One-to-One Goes Seamless

With the coming of the twenty-first century, scholars in the emerging field of m/u-learning have begun to snap the notion of seamless learning and coin the term in the relevant literature (e.g., Chen et al. 2004; Cheng et al. 2005; Thomas et al. 2004), with a greater focus on technological innovation to enable specific personalized learning activities across spaces. With the proliferation of 1:1 (one-device-or-more-per-student) setting as expounded by Norris and Soloway (2002, 2004), the time was ripe for m/u-learning researchers who used to concentrate only on designing episodic in-class or ("exclusive or") out-of-class learning activities to look into a far more ambitious domain – what if each learner has the access and even assume the ownership of his/her own mobile device, 24×7? A major international synthesis of the topic by Chan et al. (2006) has been written in the context of the "Global Researcher and Testbed Network for 1:1 Technology-enhanced Learning" (G1:1 community). The authors saw seamless learning being reframed in the context of TEL as:

> …marked by continuity of the learning experience across different scenarios or contexts, and emerging from the availability of one device or more per student. By enabling learners to learn whenever they are curious and seamlessly switch between different contexts, such as between formal and informal contexts and between individual and social learning, and by extending the social spaces in which learners interact with each other, these developments, supported by theories of social learning, situated learning, and knowledge-building, will influence the nature, the process and the outcomes of learning. (p. 23)

The paper has virtually launched the "second life" of seamless learning with a flurry of follow-up discussions and studies taking place within the community of m/u-learning. This "second life" is retrospectively known as "mobile-assisted seamless learning" (MSL) by Wong and Looi (2011) to differentiate from its "first life" or the general sense of seamless learning. Although the "second life" can virtually be seen as a "reincarnation" of the first to begin with, it is then aggressively evolving and identifying its own niche, and perhaps enriching the meaning of the fundamental notion. Still, regardless of how much the distinction between the research/practical emphases of the "two lives," there exists a lowest common denominator: the continuity of individual learners' learning experience across multiple learning spaces, particularly to connect formal and informal learning spaces.

Attuning to the theme of this book, the rest of this chapter will center on an account of the brief history of MSL (the "second life") according to our recent literature scan and analysis. The approach that we undertook in identifying the relevant papers was similar to what was employed by Wong and Looi (2011). We started with rounds of searches on Google Scholar, ERIC, Web of Knowledge, and British Education Index, with the Boolean combination of search keywords ["seamless learning" AND ("mobile learning" OR "ubiquitous learning")]. One hundred and two papers published between 2006 and March 2014 were identified as a result, i.e., an addition of 48 recent publications on top of 54 papers reviewed by Wong and Looi (2011) (i.e., an 88 % increase within 3 years). The rest of the chapters in this book that offer new insights may also be referred to where appropriate. However, unlike most of the literature review articles, the intention is not to compile thick and intentionally accurate statistics and subsequently offer purely data-driven interpretation of the state of the arts. Rather, we will qualitatively outline and trace the evolution of MSL in the following aspects: (1) the (re-)scoping of seamless learning, (2) the conceptual groundings, (3) the MSL-specific theoretical, characterization, ecological, design, methodological, and technological frameworks being developed. Rise-above discussions on the trends will then ensue in order to provide a synoptic picture of how this line of studies have been evolving and advancing over the time.

Scoping and Re-scoping Seamless Learning

Despite having a rich literature in its "first life," seamless learning is commonly seen as a special form of m/ u-learning within the TEL community. Some TEL researchers carried a relatively techno-centric perspectives that treated ubiquitous and context-aware technologies as the essential enablers of MSL without being interrupted while learners switch locations or devices (Chiu et al. 2008; Hwang et al. 2008; Yu et al. 2009). Others viewed seamless learning and ubiquitous learning as synonyms (Laisema and Wannapiroon 2013; Ng and Nicholas 2007; Wang and Wang 2008). Wong and Looi (2011) did not concur with both views as u-learning is a relatively techno-oriented notion about how ubiquitous technology supports learners in the right way, in the right place, and at the right time, based on the personal and environmental contexts in the real world (Hwang et al. 2008). To clarify the distinction between u-learning and MSL, it is good to examine some representative "scoping descriptions" of MSL or MSL space in the literature, as shown in Table 1.1. I do not refer to these "scoping descriptions" as "definitions" as none of these appears to be a formal statement that rigorously defines the meaning of MSL. Instead, they are offering new (and perhaps interrelated) insights that define salient characteristics of MSL. Meanwhile, in shaping their pedagogical framing of seamless learning, Nicholas and Ng (Chap. 13) offer a more in-depth exposition on this matter.

By cross-examining the quotations from the 14 selected publications in chronological order, one would notice a gradual shift of researchers' perceptions on MSL from a technology-enabling perspective (Chiu et al. 2008; Hwang et al. 2008; Ng

Table 1.1 The scoping descriptions of MSL or MSL space in the literature

Publication	Scoping description
Chan et al. (2006)	(See the quote on p. 3 of this chapter)
Yang (2006)	"The ubiquitous learning environment can connect, integrate and share learning resources in the right place at the right time by an interoperable, pervasive and seamless learning architecture." (p. 188)
Ng and Nicholas (2007)	"Sharples, Taylor and Vavoula (forthcoming) *[note:* (Sharples et al. 2007)*]* have proposed a model of learning for the mobile age, but we argue that their model omits one important consideration … they have highlighted the physical ubiquity of the technology without adequate consideration of the conditions for seamless learning. In presenting their model, they continue a perhaps unconscious tradition of the mobile learning field to highlight mobility over learning. Our argument is that at least in the mainstream school education context, seamless learning requires planned interactions between mobile and stable technologies." (pp. 3–4)
Chiu et al. (2008)	"Ubiquitous learning environments enable seamless learning at anywhere and anytime. The learners are allowed to learn without being interrupted while moving from place to place." (p. 259)
Hwang et al. (2008)	"A context-aware ubiquitous learning environment enables seamless learning from place to place within the predefined area." (p. 84)
Rogers and Price (2009)	(*Note: This appears to be a synthetic definition for m-learning, u-learning, and MSL.*) "Central to these notions is the idea that mobile technologies can be designed to enable children to move in and out of overlapping physical, digital and communicative spaces. The mobility can be achieved individually, in pairs, in small groups, or as a whole classroom …" (pp. 4–5)
Obisat and Hattab (2009)	"The modern e-learning system must be able to offer personalized support and learning solutions in real-time. Such an approach combines real-time assessment, learning, and pedagogical considerations into one seamless learning activity." (p. 126)
Baloian and Zurita (2012)	"The ubiquitous availability of mobile devices promotes the seamless learning notion that envisages the embodiment of learning into everyday living." (p. 7000)
Wong (2012)	"There may be episodic learning efforts taking place in different contexts, either externally facilitated (e.g., started from a teacher) or self-initiated. However, such isolated learning gains may later be converged as they may mediate the same learner's learning efforts in the future." (p. E20)
Wong (2013a)	"We re-conceptualize the nature of 'seamless learning environment' from an individual learner's perspective by adapting Barron's (2006) definition of learning ecology as 'the combination of physical or virtual (living) spaces that a person is situated or encounters in his/her daily life that provides opportunities of learning.'" (p. 209)
	"… to re-conceptualize the nature of seamless learning from an individual learner's perspective, i.e., students' self-generation of learning contexts within and across their living spaces. Students should ultimately become life-long autonomous learners who are able to decide when, where and how to learn with self-identified resources within their learning spaces." (p. 210)

(continued)

Table 1.1 (continued)

Publication	Scoping description
Ozdamli (2013)	"… make learning more personal and meaningful because seamless learning refers to student-centered learning. Students have to think on their own, take initiative, monitor their own progress, solve problems and therefore are more aware of the complexity of how their new knowledge is constructed and presented." (p. 603)
Milrad et al. (2013)	"… genuine seamless learning is about treating all the learning spaces and resources that learners have access to as ingredients to facilitate their ongoing self- and co-construction of knowledge, rather than believing in knowledge as composed of universal facts that are best learned through didactic teaching."
Sharples et al. (2012)	"Seamless learning is when a person experiences a continuity of learning across a combination of locations, times, technologies or social settings." (p. 24)
	"Seamless learning may form part of a wider learning journey that spans a person's life transitions, such as from school to university or workplace." (p. 24)
	"Seamless learning can best be seen as an aspiration rather than a bundle of activities, resources and challenges." (p. 25)
Looi and Wong (2013)	"A more productive view of learning sees learning as happening continuously over time and learning experiences as being enriched when similar or related phenomena are studied or seen from multiple perspectives. In more formal settings, learners may learn canonical knowledge about a subject or topic, while in more informal settings, learners experience the subject or topic in its natural settings or in different contexts, thus achieving more holistic notions of learning and literacy. Learners will almost naturally and continually enhance their knowledge and skills to address problems and participate in a process of continuous learning."
Toh et al. (2013)	"This notion of seamless learning refers to the integrated and synergistic effects of learning in both formal and informal settings, which is distributed across different learning processes (emergent or planned) as well as across different spaces (in or out of class)."

and Nicholas 2007; Yang 2006) to a curriculum design perspective (Looi and Wong 2013; Obisat and Hattab 2009) (Obisat and Hattab were in particular highlighting the need of integrating assessment into the seamless learning experience) to the foregrounding of the roles of learning spaces (Baloian and Zurita 2012; Rogers and Price 2009; Wong 2013a) to the fostering of a learning culture (Milrad et al. 2013; Ozdamli 2013; Sharples et al. 2012; Toh et al. 2013; Wong 2012, 2013a).

Subsequent efforts focused on enriching the learning notion through expositions and studies from diverse angles and theoretical framings. In particular, Ng and Nicholas (2007) urged researchers and practitioners to look beyond device/learner mobility in MSL practice by incorporating stable technology (desktop computers, etc.) into the picture. This argument may have virtually become a prelude of the more recent MSL technological frameworks of "learning hub" and cloud-based personalized learning environment (PLE) which will be elaborated in "The MSL-Specific Technological Framework" section of this chapter.

The expositions of Chiu et al. (2008) and Hwang et al. (2008) seem to be inherently contradictory as the former talks about "anytime, anywhere learning" (p. 259) while the latter stipulates "learning within a predefined area" (p. 84). Hwang et al.'s (2008) exposition is perhaps pertaining to one of the well-studied solutions of u-learning environments that leverage location-based services to tailor learning trails to a specific location or object (e.g., those using RFID or QR tags). Examples of such MSL interventions are also reported in Kurti, Spikol and Milrad (2008), Rogers and Price (2008), and Shih and Tseng (2009). In contrast, the Global Positioning Systems (GPS) or the Geographic Information Systems (GIS) help the MSL designers and learners in breaking the barrier and affording learning activities to be carried out perhaps in much wider areas. For instance, Zurita and Baloian (Chap. 10) developed two systems rooted in the notions of situated learning and geo-collaboration that leverage such technologies. More MSL designs that adopted the technologies are accounted in Maldonado and Pea (2010), Ogata et al. (2008), and Sollervall and Milrad (2012), among others.

In a broader view, "learning anytime, anywhere" was once a "slogan" for e-learning in general and later being taken over by m-learning. The related question is that whether "learning anytime, anywhere" is equal to "continuity of learning across multiple spaces?" If so, the seamless learning notion would not justify its own niche. Indeed, we see some of the reported interventions were loosely characterized in the literature as seamless learning designs. Yet the learning activities were somewhat repetitive, perhaps in a behaviorist manner, albeit across time and spaces (e.g., Huang et al. 2007; Miyata et al. 2010; Narayanansamy and Ismail 2011; Redd 2011; Tillman et al. 2012). Sharples (Chap. 2) coined the term "flow learning" to characterize such a learning approach, i.e., to induce a flow state "such that learners are so engaged in a mobile learning activity that they lose awareness of their surroundings" (p. 1). The way we see such an approach is, however, that it falls back to the "classic" e-learning characteristic of "learning anytime, anywhere" without the consideration of what unique environmental constructs in varied learning spaces including artifacts, tools, and/or people could facilitate multifaceted learning tasks – e.g., physical spaces for situated learning and authentic data collection, online platforms for peer discussions. As Sha (Chap. 5) has stated, "One of the fundamental challenges of the twenty-first century learners is not only what they learn, but also how and when they learn in the ways that make meaningful learning happens." (p. 4)

Subsequent studies then began to accentuate the natures of and the roles that various learning spaces may play in mediating the seamless learning journeys. Baloian and Zurita (2012) coined the term "embodiment" to underscore the importance of mobile and seamless learners' blending into, and interacting and having conversations with, the physical and social worlds (or "everyday living"). This marks a departure from the earlier ubiquitous technology-driven interventions which typically treated learners as passive "consumers" of (perceived static) physical contexts (Whitworth 2008; Wong 2013a). The arguments are also consistent with what Pea (2009) postulated, "We need to treat the activities and life experiences of the learners throughout the day as our units of learning design, description and explanation."

Whereas "learning in the right way at the right space and the right time" seems to be the key to general m-learning and situated learning, perhaps the defining feature of seamless learning is "bridging" the multifaceted learning efforts across multiple spaces. This is what the most recent set of papers cited in Table 1.1 predominantly were advocating (known as "connected learning" in Sharples (Chap. 2)). Building on the quote from Wong (2012) in Table 1.1, Wong (2013b) envisaged a spiral-style construct across MSL tasks (or "learning cycles" in the paper) where "in the present cycle, the explicit target knowledge to learn, the learning activity types, the skill to learn and apply, the mobile affordances to use, and the student artifacts to reuse and create, are all building on or rising above the previous cycle." (p. 335) Without such an "organic" bridging of learning experiences and learning gains despite enactments of a variety of learning tasks across multiple spaces, one's learning journey will remain fragmented, if not repetitive.

As observed by Milrad et al. (2013), "recent studies on seamless learning have been extending from teacher-facilitated classroom or outdoor learning into nurturing autonomous learners" (p. 96). Seamless learning is now seen as an aspiration (Sharples et al. 2012), a "habit-of-mind" (Wong and Looi 2011), or a set of metacognitive abilities (Sharples, Chap. 2) or "schematized and habitual regulatory strategies" in psychological term (Sha et al. 2012b) that should span one's lifetime and make one become a lifelong learner. With more and more level- or institution-wide 1:1, 24×7 initiatives being implemented (e.g., Bentley et al. 2010; Looi and Wong 2014; Ng and Nicholas 2009; Pegrum et al. 2013; Vogel et al. 2007) (see also: Looi et al. Chap. 21), the fostering of a culture of seamless learning is now on the table.

In a nutshell, the trajectory of evolution of the seamless learning notion probably signifies that the practice of this notion should go beyond the mindset of offering learners the "logistic convenience" in contextual and cross-contextual learning. The key is to facilitate and nurture genuine transformations of beliefs about and habits of learning among the learners. Ultimately, if a one-statement definition of seamless learning is still desired, perhaps we can adopt and adapt from Sharples et al.'s (2012, p. 24) exposition, "Seamless learning is when a person experiences a continuity of learning, *and consciously bridges the multifaceted learning efforts*, across a combination of locations, times, technologies or social settings." We insert the "bridging" element into the exposition since "a continuity of learning" alone does not necessarily encapsulate the stated condition – even the above-stated "learning anytime, anywhere, (repetitively)" designs may fit this description. With this relatively concise definition (though perhaps requiring further unpacking), the field would not need to always quote the wordy "scoping description" as put forward by Chan et al. (2006).

The Conceptual Groundings

Seamless learning or MSL has been loosely referred to by some literature as a learning *theory* (e.g., Fang et al. 2011; Tsoi and Dekhane 2011; Wei 2012). However, just like inquiry learning and m-learning, seamless learning should instead be seen as a learning notion or a learning approach at least till it is convincingly theorized. To start with, Chan et al. (2006) was meant to be an initial characterization effort on

MSL as a rise above of the co-authors' synoptic and critical analysis of the state-of-the-arts of general m-learning. Over the years, scattered work on modeling, framework building, and initial theorization of MSL took place, which will be synoptically presented in coming sections. Before that, let's survey existing general learning theories, frameworks and concepts that the MSL researchers have rooted their studies in. This would assist us in making better sense of the nature of seamless learning and shed light on the future research and practical directions of the field.

A summary of the types of conceptual grounding is given in Table 1.2. Note that papers with brief mentioning of certain conceptual groundings without clear evidences of their actual designs or analysis being informed by the stated concepts are *not* included in the table.

The first set of MSL studies, typically those which are technology innovation-oriented, have exhibited the tendency of associating their intervention designs to numerous TEL concepts or approaches, such as m/u-learning in general, pervasive learning, distance learning, blended learning, personalized learning or PLE, and ICT as cognitive tools. Also being rooted for learning designs are context-awareness/sensitivity/adaptivity, which are more general technological architectures than learning approaches.

The second set of studies was framed by the common characteristic of foregrounding the roles of learning spaces or scenarios in mediating learners' deep learning, such as situated learning, authentic learning, experiential learning, scenario-based learning, conversation theory, and ecology of resources. Nonetheless, the theoretical framings assumed by some of these studies appeared to be more orientated toward general m/u-learning than seamless learning. Experiential learning is perhaps the only learning notion among the stated ones that inherently encapsulates the essence of seamless learning. Guided by Kolb's (1984) four-task cyclical model for experiential learning (concrete experience, reflective observation, abstract conceptualization, and testing in new situations), two MSL studies (Lai et al. 2007; Song et al. 2012) designed learning flows with the four learning tasks being carried out and *bridged* across multiple learning spaces.

A pertinent notion is distributed cognition (DCog) which has provided the grounding for perhaps the second largest set of MSL studies among all the relevant theoretical underpinnings (six of them; after situated learning with seven; see Table 1.2). DCog is devoted to the study of the representation of knowledge both inside the heads of individuals and in the world, the propagation of knowledge between different individuals and artifacts (broadly defined to include instruments, signs, languages, and machines that mediate activities) and the transformations that external structures undergo when operated by individuals and artifacts (Flor and Hutchins 1991). Combining both social and cognitive aspects, a DCog perspective (Salomon 1993) suggests that learning should not be perceived as individual cognitive activity, but as a process distributed across individuals and artifacts. Hutchins (1987) also discussed "collaborative manipulation," the process in which we leveraged on artifacts designed by others (and ourselves) to share ideas across time and space.

All these core assertions of DCog mesh well with some of the salient characteristics of seamless learning, such as the bridging of individual and social learning,

Table 1.2 The conceptual groundings of seamless learning as adopted by the literature

Category	Conceptual grounding	Referencing literature
TEL concepts or approaches	m/u-learning (in general)	Handal et al. (2013), Hwang et al. (2008), Ng and Nicholas (2007), Shih et al. (2010), Wyeth et al. (2008)
	Pervasive learning	Benamar et al. (2013), Bouzeghoub et al. (2011), Khan and Zia (2007), Muñoz-Cristóbal et al. (in-press)
	Distance learning/ blended learning	Bentley et al. (2010), Muyinda (Chap. 11 of this book)
	Personalized learning or PLE	Bentley et al. (2010), Gillot et al. (2012), Looi et al. (2009), Obisat and Hattab (2009), Tabuenca et al. (2012)
	ICT as cognitive tools	Laru and Järvelä (Chap. 23), Seow et al. (2009)
	Context-awareness/ sensitivity/adaptivity	Li et al. (2009), Yu et al. (2009), Zhao and Okamoto (2011), Zhong et al. (2013)
Learning notions that foreground the roles of learning spaces (contexts)	Situated learning	Bouzeghoub et al. (2011), Chen et al. (2008), Kurti et al. (2008), Metcalf et al. (2008), So et al. (2012), Bachmair and Pachler (Chap. 3), Zurita and Baloian (Chap. 10)
	Authentic learning	Cinque (2013), Ogata et al. (2008)
	Experiential learning	Lai et al. (2007), Song et al. (2012)
	Scenario-based learning	Metcalf et al. (2008)
	Conversation theory	Zhao and Okamoto (2011)
	Distributed cognition	Laru and Järvelä (Chap. 23), Looi et al. (2010), Otero et al. (2011), Seow et al. (2009), Song and Kong (Chap. 4), Wong et al. (2012b)
	Ecology of Resources	Specht (Chap. 7)
Pedagogic- or constructivist-inspired notions	Socio-constructivism	Roger and Price (2008), Spikol and Milrad (2008)
	Knowledge building	Maldonado and Pea (2010), So et al. (2012)
	Knowledge spirals	Zhang and Maesako (2009)
	Inquiry learning	Gillot et al. (2012), Maldonado and Pea (2010), Rogers and Price (2008), Song (2014)
	Sense/meaning making	Toh et al. (2013), Wong (2013a), Wong et al. (2010)
	Learner-generated contexts	Wong (2013a)
	Learning with patterns	Zurita and Baloian (Chap. 10)
	Scaffolding	Laru and Järvelä (Chap. 24), Lin et al. (2008)
	Pedaogogical/ collaboration scripts	Kohen-Vacs and Ronen (Chap. 23), Laru and Järvelä (Chap. 24), Tissenbaum and Slotta (Chap. 12)
	Cognitive apprenticeship	Zurita and Baloian (Chap. 10)
	Differentiated instructions	Looi et al. (2009)
	Reflection in/on action model	Cinque (2013)
	SECI model	Chang and Chen (2007), Zhang and Maesako (2009), Baloian and Zurita (2012)

(continued)

Table 1.2 (continued)

Category	Conceptual grounding	Referencing literature
Autonomous learning approaches	Self-guided exploration	Vogel et al. (2007)
	Self-regulated learning	Laru and Järvelä (Chap. 23), Sha (Chap. 5)
	Self-directed learning	El-Bishouty et al. (2010), Ozdamli (2013), Wong (2013b), Zhang et al. (2010)
	Lifelong learning	Kalz (in-press), Seta et al. (2014), Tabuenca et al. (2012)
	Transformation of participation	Toh et al. (2013)

the learners' appropriation of elements (artifacts) available in specific learning spaces to support their learning, and the bridging of cross-space learning efforts mediated by specific artifacts (such as the personal mobile device, or student artifacts created in previous activities). Relating to the perspective of the intersection of DCog and seamless learning, a learning context is not necessarily confined within a specific learning space and a specific time frame (a take that many general m/u-learning studies would adopt). Instead, a learning context may span across time and spaces, and constantly reconstructed through switching of learning tasks. Thus, it is not surprising that scholars tapped on DCog when constructing generic theoretical or methodological frameworks for seamless learning. These frameworks will be elaborated in the following sections.

The third set of MSL literature placed its emphasis on the pedagogical aspect and/or constructivist affinity of seamless learning and made references to knowledge building, knowledge spirals, inquiry learning, sense making or meaning making, learner-generated contexts, learning with patterns, scaffolding, pedagogical or collaboration scripts, cognitive apprenticeship, differentiated instructions, and the "reflection in/on learning" model. Again, in the eyes of MSL researchers and designers, every knowledge construction process should be extended and bridged, rather than being confined within one single learning session.

In addition, not as a learning notion or a pedagogical paradigm but a process framework for knowledge management, the SECI model (Nonoka and Takeuchi 1995) was adopted by three MSL studies in developing their respective process frameworks or solutions. The SECI model describes the dynamics of knowledge evolution as a knowledge spiral within a knowledge-creating enterprise, with the process of knowledge creation involving four cyclical stages: Socialization, Externalization, Combination, and Internalization – which again should be carried out across time and space.

A smaller set of studies associated their designs or analyses with the notions of self-guided exploration, self-regulated learning, self-directed learning, lifelong learning, and transformation of participation – all can be seen as variations of autonomous learning. Indeed, seamless learning itself can be classified along with this group of notions that aim to promote certain self-regulatory and habitual learning cultures in individual learners.

Through the analysis of the seemingly diverse theoretical underpinnings of seamless learning in this section, the sociocultural perspective of learning consistently stands out as the implicit guiding philosophy for the conceptualization, implementation, and interpretation of the notion. Constructivism and socio-constructivism become the common threads that weave together individual or groups of learners' learning efforts and experiences across multiple spaces, (perhaps) with the eventual goal of fostering a sustainable sense of learning ownership in them. How such an "aspirational" way of learning can be operationalized will be further expounded in the next four sessions, where various forms of frameworks developed specifically for MSL in the past 8 years will be presented.

The Theoretical Expositions, and the Characterization and Ecological Frameworks for MSL

This section focuses on consolidating MSL researchers' theoretical elucidations and their views on the characteristics and ecologies of the MSL, a rise above from the expositions made by the earlier seminal papers and the existing learning theories. Encapsulated in this and subsequent sections are frameworks which are reasonably generic. Other frameworks that are meant for specific intervention designs or solutions are precluded.

Table 1.3 presents the relevant expositions and frameworks, with the rightmost column listing subsequent publications that espoused the respective frameworks in their designs and/or analyses. Publications that merely cited the frameworks but were not genuinely building on those in the reported studies are excluded from the column.

Theoretical Expositions of MSL

Although the first two theoretical expositions on the nature of MSL are not "frameworks" with well-defined structures, the conceptual dyads are nonetheless inspiring ones. The two expositions share the common interest on exploring the potential contributions of artifacts to the overall learning process – in the perspective of DCog.

In particular, Otero et al.'s (2011) key explication was pertaining to external representations (ER) (Zhang 1997), a special form of "artifacts" in a broader sense. ERs refer to various learning resources (specifically, representations of structures and knowledge in the world) that are used or co-constructed by (seamless) learners. These ERs would provide the common ground in mediating collaborative seamless learners who may be separated by time and space, and may not be sharing the same physical space and representations. The explication bears resemblance with Wong et al.'s (2012b) framing of the DCog-informed analytical method that they developed (see the next section). Nevertheless, Otero et al. (2011) moved one step

Table 1.3 The theoretical expositions, and the characterization and ecological frameworks for MSL

Type	Title or Description	Publication(s) where the framework is originated from	Publications that referred to the framework as their theoretical underpinning or analytic framework
Theoretical expositions	Socio-emotional perspective of External Representations	Otero et al. (2011)	
	Student artifacts as the mediator for learning across spaces	So et al. (2009), Wong et al. (2012b), Wong and Looi (2010)	
Characterization frameworks	Three-dimensional framework of seamless learning scenarios	Deng et al. (2006)	
	Two-dimensional matrix of seamless learning spaces	W. Chen et al. (2010), So et al. (2008)	Ogata and Uosaki (2012), Toh et al. (2013), Uosaki et al. (2010)
	"10 Dimensions of Mobile Seamless Learning (10D-MSL)"	Wong (2012), Wong and Looi (2011)	de Waard (2013), De Waard et al. (2014), Koh and Looi (2012), Milrad et al. (2013), Sollervall and Milrad (2012), Tabuenca et al. (2012), Wong (2013b), Glahn (Chap. 18), Hwang and Shih (Chap. 16), Kohen-Vacs and Ronen (Chap. 23), Nordmark and Milrad (Chap. 18), Wong et al. (Chap. 15), Zurita and Baloian (Chap. 10)
	"Seven types of mobile seamless learning"	Uosaki et al. (2013) (see also: Chap. 9)	
	"The learning activity spectrum"	Wu and Liu (Chap. 22)	
Ecological frameworks	"Person-centered sustainable model for mobile learning"	Ng and Nicholas (2013)	
	"A framework for seamless learning"	Looi et al. (2010), Seow et al. (2008)	Metcalf et al. (Chap. 6)
	The niche of seamless learning	Song and Kong (Chap. 4)	
Cognitive frameworks	"A Self-Regulated Learning Model for MSL"	Sha (Chap. 5)	
	"A distributed cognition system"	Laru and Järvelä (Chap. 24)	

further by calling for the study of socio-emotional influences in investigating and designing learners' use and co-construction of ERs.

Somewhat congruent with Otero et al. (2011) is So et al.'s (2009) explication, albeit with a special focus on student-generated artifacts in mediating and bridging subsequent learning activities. If the creation of student artifacts is viewed as a means of meaning making, such an activity can be conceptualized (in a social semiotic perspective) as meanings made through the process of materially realizing signs and transforming available resources into new signs (Kress 2011, cited in: Charitonos et al. 2012). In a related vein, So et al. (2009) tapped on Lemke's (1999) distinction between typological and topological representations in framing their MSL intervention design for a mobilized Chinese heritage trail "Chinatown 2.0." The trail combined in-situ student artifact creations (textual notes) and class-wide post-trip discussions on the artifacts posted online. Typological representations are language-based and discrete, while topological representations are space-based and continuous. The student artifacts are typological representations of the students' meaning made on the topological representations (the physical site) which can support the students in deepening their understanding, socially, beyond the field trip. In this regard, Wong and Looi (2010) positioned such in-situ student artifacts as a means for fostering further peer learning and the bridging of personal and social meaning making (Wong et al. 2010).

According to the MSL literature, there is a considerable number of intervention designs that adopted this principle and specifically emphasized the significance of post-trip social meaning making of the in-situ artifacts over a period of time (ranging between 2 weeks and year-long), including Chinatown 2.0 (So et al. 2009), My Mobile Mission (Wyeth et al. 2008), 3R (Seow et al. 2009), "Move, Idioms!" (Wong et al. 2010), SEAMLESS Project (Looi et al. 2010; Song et al. 2012), LET'S GO! (Maldonado and Pea 2010), Chiku learning trail (Hwang et al. 2011, as cited in Milrad et al. 2013), Personal Inquiry (Anastopoulou et al. 2012, as cited in: Milrad et al. 2013), Sentosa Island learning trail (So et al. 2012), Museum of London learning trail (Charitonos et al. 2012), and MyCLOUD (Wong et al. 2012a).

The Characterization Frameworks

The next five frameworks can be seen as the outcomes of the field's ongoing characterization efforts for MSL. The first framework was delineated by Deng et al. (2006) to inform the design and development of a resource sharing platform for the G1:1 community. The framework was intended to characterize seamless learning scenarios simply in three dimensions: locations, scales of co-learners, and learning activity or pedagogical models.

The granularity of such a framework was substantially refined through Wong and Looi's critical analysis of the MSL literature published between 2006 and March 2011 (Wong 2012; Wong and Looi 2011). The unpacking effort has resulted in the distillation of ten dimensions of MSL (retrospectively known as 10D-MSL in Wong's subsequent publications):

(MSL1) Encompassing formal and informal learning
(MSL2) Encompassing personalized and social learning
(MSL3) Across time
(MSL4) Across locations
(MSL5) Ubiquitous access to learning resources
(MSL6) Encompassing physical and digital worlds
(MSL7) Combined use of multiple device types
(MSL8) Seamless switching between multiple learning tasks
(MSL9) Knowledge synthesis
(MSL10) Encompassing multiple pedagogical and leaning activity models (Wong and Looi 2011; MSL5 according to Wong 2012)

The framework stimulated discussion on "what seams (gaps) do we remove?" – a challenge that is posed to the designers of MSL (or seamless learning in general). Note that Wong and Looi did not advocate the removal of all the ten "seams" in every single MSL design. They instead positioned the "seams" as dimensions – some of which are more appropriate to be represented as continua than dichotomies. This is because they are cognizant that different intervention designs may encompass different combinations of "removed seams," depending on the respective natures of the subject domains, main pedagogical or learning approaches adopted, and resource constraints.

Subsequently, Wong (2012) developed a visualizing diagram for 10D-MSL (Fig. 1.1) to clarify the relations among the 10 dimensions. Specifically, MSL3 (across time) and MSL4 (across locations) are identified as the highest-level dimensions that embody all other dimensions. Within this two-dimensional space, there

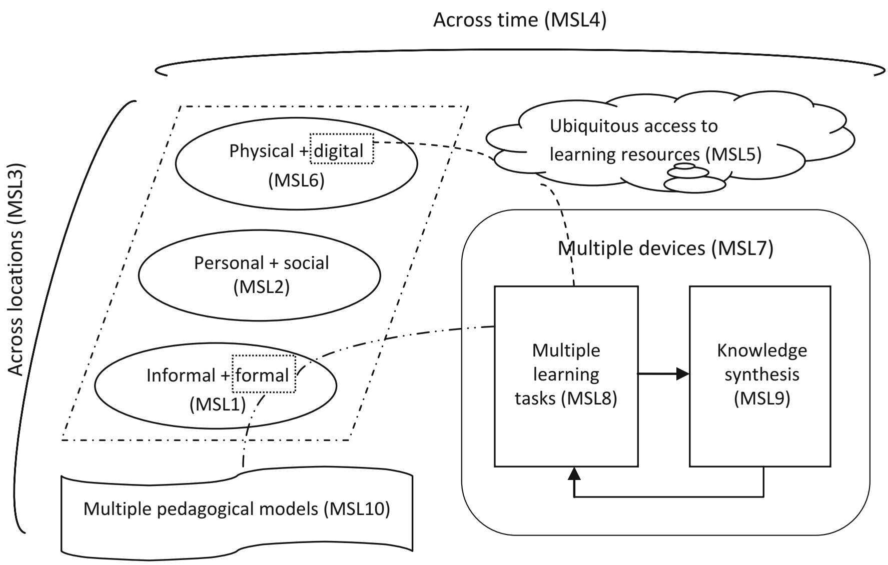

Fig. 1.1 Visualization of the 10D-MSL dimensions (Wong 2012, p. E20)

exist three specific continua of learning (sub)spaces, namely, MSL1, MSL2, and MSL6, which are loosely grouped together in the parallelogram. Under the multidimensional learning spaces, a learner may use multiple devices (MSL7) to mediate all his/her MSL endeavors. Two external inputs, MSL5 and MSL10, serve for initiating or enhancing the learner's specific learning tasks, are accessed by the learner through the formal learning space and the digital world, respectively. With the interplay of all the previously mentioned dimensions, a learner will be able to perform, and seamlessly switch between, multiple learning tasks (MSL8), which may lead to knowledge synthesis (MSL9). However, because of the perpetual nature of seamless learning, the learning outcomes of MSL9 may be fed back to MSL8, that is, another round of learning activities that takes place in the future.

Since the first introduction of the 10D-MSL model, it has been espoused by a handful of subsequent studies to inform their intervention designs or analyses of their designs. Milrad et al. (2013) retrospectively situated and contrasted five MSL designs (from Taiwan, the United Kingdom, Sweden, Singapore, and Japan) with varied emphases in this dimensional space to stress the diversity and open-endedness of the learning approach. Similar analyses were also carried out by De Waard et al. (2014); Hwang and Shih (Chap. 16), Koh and Looi (2012), Kohan-Vacs and Ronen (Chap. 23), Sollervall and Milrad (2012), and Zurita and Baloian (Chap. 10) on the authors' respective intervention designs. Elsewhere, Tabuenca et al. (2012) developed a questionnaire to analyze learning practices of adults, with 7 of the 10D-MSL dimensions being incorporated as subscales of the instrument. Wong himself has also mapped 10D-MSL to Facilitated Seamless Learning (FSL), a learning process framework for MSL intervention design that he developed (see the next section). Meanwhile, in developing their generic seamless language learning framework (i.e., a domain-specific framework), Wong, Chai, and Aw (Chap. 15) adopted 6 of the 10D-MSL dimensions as part of the 13 design principles for seamless language learning. Similarly, Glahn (Chap. 19) hybridized 10D-MSL and "7 clusters of research challenges of mobile learning" Börner et al. (2010) to frame and analyze four seamless security and defense learning systems.

Another framework meant for characterizing and categorizing the potential types of learning carried out by individual seamless learners was put forward by So et al. (2008) and later revised by Chen et al. (2010). As shown in Fig. 1.2, the learning types are classified based on two factors: "physical setting" (in-class and out-of-class) and "planned vs. emergent learning." Though being positioned as a learning-space categorization framework (rather than a learning process framework) to begin with, the six double-sided arrows in the center of the diagram signify potential cross-boundary seamless learning of any individual learner. Chen et al. (2010) argued that learning experiences can be deepened when a virtuous cycle is created, where learners can establish continuity of experiences connecting multiple learning spaces. In cases where there are disjunctures in the cycle, learning tends to be more superficial and perhaps irrelevant to the lives of participants. The revised framework has then informed the same research team in developing their methodological framework for MSL research (Toh et al. 2013) (see "The Methodological Frameworks for MSL Studies" section). Likewise, Uosaki et al. (2010) mapped the

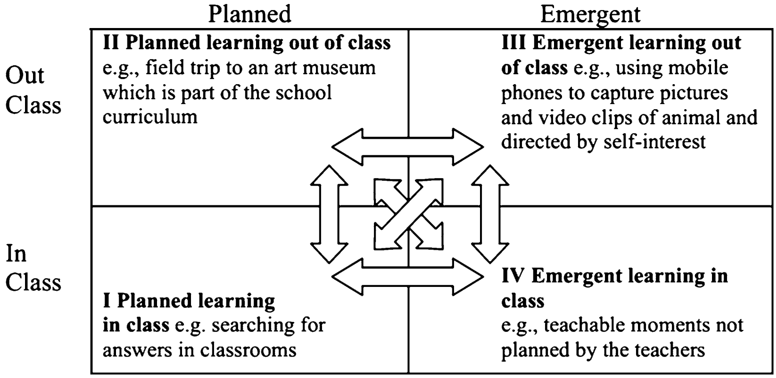

Fig. 1.2 A matrix of seamless learning spaces (Chen et al. 2010, adapted from So et al. 2008)

cyclic learning process for their seamless English vocabulary learning design into the framework – (1) preview (out-of-class planned learning), (2) lessons (in-class planned/ emergent learning), (3) review (out-of-class planned learning), and (4) expanded study (out-of-class unplanned learning).

Yet another categorization framework is put forward by Ogata et al. (Chap. 9) who distinguish MSL into seven types situated in two-dimensional spaces: (1) "'in-class OR out-of-class only' versus 'encompassing in-class and out-of-class' learning" and (2) "fixed versus mobility of the technology" (i.e., the use of PC versus mobile devices). This framework seems to foreground "encompassing in-class and out-of-class learning" and the mobility of the learners as two major criteria to gauge the level of seamless-*ness* of a particular seamless learning design.

In the meantime, Wu and Liu (Chap. 22) proposed a simpler framework where various types of learning activities are situated along a spectrum of learning activities, differentiated by the scale of participated learners – with individual learning and community-based learning in the either end of the spectrum, and collaborative learning somewhere in between (corresponding to MSL2 of 10D-MSL). The chapter then explicated the gap among these learning settings and recommended socio-technological solutions accordingly.

The Ecological Frameworks

Various scholars portrayed three ecological frameworks to stipulate what it takes to create environments that are conducive for promoting a seamless learning culture. The first two of the frameworks seem to be situated at the meso level while the last one puts forward a micro-level learning ecology.

Ng and Nicholas (2013) delineated a "person-centered" model to describe how the interactions between stakeholders and between users and devices influence the sustainability of m-learning innovation in a formal education institution. This model is intended for informing the implementations of school-based 1:1 (but not necessarily 24×7) initiatives in general. Nevertheless, it could as well be applied to MSL practice, as it takes into account the presence of parents and the wider community and their interactions with the school leaders, teachers, and students (see Fig. 1.2 in Ng and Nicholas (2013)).

While Ng and Nicholas developed their model from the perspective of individual education institutions, Seow et al.'s (2009; see also: Looi et al. 2010) DCog-informed framework centers cognitive tools as a means to weave various other seamless learning components (space, time, context, community, and artifacts) together in mediating a learner's ongoing learning journey. Rooted in Jonassen and Reeves' (1996) notion of cognitive tools, Seow et al. characterized mobile devices and online portals as those where learners are able to offload tasks, recall information over time, and modify their initial thoughts. Such a view bears resemblance with the notion of "learning hub" which will be elaborated in "The Technological Frameworks for MSL" section. In Chap. 6 of this book, Metcalf, Jackson, and Rogers applied this framework to analyze four m-learning systems which they positioned as MSL designs. In turn, they identified context as a key attribute of seamless learning. Yet in view of the long-term goal of cultivating capacity for higher-order thinking, they cautioned that being over reliant on highly contextualized interventions would result in instrumental rather than critical engagement. This argument is congruent with MSL9 (knowledge synthesis – encompassing prior and new knowledge, and multiple levels of thinking skills) in 10D-MSL.

Extended from Barab and Roth's framework of "curriculum-based ecosystems" (Barab and Roth 2006), the third ecological framework for MSL as put forward by Song and Kong (Chap. 4) offers a philosophical lens to conceptualize the ecology of resources for seamless learning. The framework postulates that the intersection of affordance network (functionality-bound possibilities in an environment), effectivity sets (the attunement and employment of affordance network by individual and groups of learners), and the designed seamless learning environment would constitute the "niches" (sets of affordances or experiences) of seamless learning. Although the framework in its present form seems to fit better in describing situated learning in general, there is a potential for it to be further specificated to interpret the "niches" of genuine seamless learning where bridging of multifaceted learning efforts across spaces is foregrounded.

The Cognitive Frameworks

Two cognitive frameworks are presented in Chaps. 5 and 24, respectively, which mark two early attempts (since Otero et al. 2011) in bringing a psychological perspective to seamless learning. In Sha's (Chap. 5) self-regulated learning (SRL) model of MSL, the notion of self-regulation as agency is "at the nexus of the framework, linking the social, cognitive, and metacognitive affordances of mobile tools, and the importance of teachers' and parental autonomy supports." (p. 1).

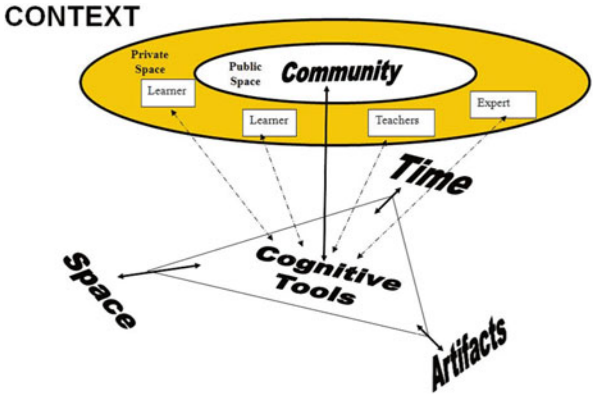

Fig. 1.3 A seamless learning framework (Seow et al. 2009)

This model appears to be similar to Seow et al.'s (2009) DCog-informed seamless learning framework (Fig. 1.3). The fundamental difference lies in the core agency that consolidates an individual learner's seamless learning ecology – the cognitive tools (i.e., focusing on concrete learning activities, mediated by the tools) versus the self-regulatory behavior (i.e., centering in the habit-of-mind). A model that perhaps reconciles the two views of seamless learning ecology is the model of distributed cognitive system elicited by Laru and Järvelä (Chap. 24) where learners' (metacognitive) knowledge about regulatory processes is explicitly shown. In the model, a variety of devices are characterized as "SRL cognitive tools" that afford the promotion of "socially shared regulation of learning … and prompting learners to metacognitively consider features of their work across levels of self-, co- and shared regulation." (pp. 6)

The Design Frameworks for MSL

Eleven MSL design frameworks will be presented in this section, as summarized in Table 1.4. As compared to those presented in the previous section, these frameworks are more pragmatic in nature and are meant for informing the operationalization of research and practice.

"Deconstruction and Reconstruction" of the Curriculum

The "curriculum mobilization cycle" is a curriculum redesign process model which was aptly associated by the developers, Zhang et al. (2010), using the metaphor of *deconstructing-reconstructing* (the existing formal curriculum). The process consists of six cyclic steps: (1) Deconstructing: Analyzing learning objectives and student learning difficulties, (2) Brainstorming: Gathering ideas and resources

Table 1.4 The design frameworks of MSL

Type	Title or Description	Publications
Curriculum design framework	Curriculum mobilization cycle	B. H. Zhang et al. (2010)
Pedagogical or learning process framework	Facilitated Seamless Learning (FSL) framework	Wong (2013b)
	Blended mobile learning model	Hwang and Shih (Chap. 15)
	Knowledge building process from diverse learning approaches	Chang and Chen (2007)
	Knowledge spiral-based ecosystem of learner development	H. Zhang and Maesako (2009)
	A process framework for learning scaffolds in m-learning setting	Lin et al. (2008)
	Design principles for m-learning field trips across multiple settings	So et al. (Chap. 16)
	Model of the pedagogical considerations of seamless learning	Nicholas and Ng (Chap. 12)
	Mobile Digital Storytelling (mDS) workflow	Nordmark and Milrad (Chap. 16)
Domain-specific design framework	The learning flow of "Inquiry-Based Science Teaching" (IBST)	Gillot et al. (2012)
	Generic Seamless Language Learning (SLL) framework	Wong et al. (Chap. 14)

based on student learning scenarios, (3) Composing: Developing student learning tasks and resources, (4) Reconstructing: Stitching different pieces to form a coherent mobile curriculum, (5) Implementing: Students carrying out learning activities in and out of classroom, (6) Summative evaluating: Reflecting and evaluating the effectiveness and informing new design cycles.

This process model was applied to SEAMLESS Project (Looi et al. 2010, 2011; Sha et al. 2012a; Toh et al. 2013; Zhang et al. 2010) in their team members' 2-year science curriculum redesigning effort at Primary 3–4 (9–10 years old) levels in Singapore, which is perhaps the longest-term seamless learning intervention ever enacted to date. The team is now planning to scale up the curriculum to five schools with a new curriculum code named "WE Learn" (Looi et al., Chap. 21), with the framework continuing to guide the curriculum redevelopment in the adopting schools. Nevertheless, this is in fact a general curriculum redesign model, which can be applied to intervention redesign informed by any other learning notion or model.

The Generic Learning Process Design Frameworks

A learning process design framework that is intended to encapsulate the essence of seamless learning is the Facilitated Seamless Learning (FSL) framework. Wong (2013b) contrasted the notions of self-directed seamless learning and facilitated seamless learning to highlight the distinction between self- and externally-initiated

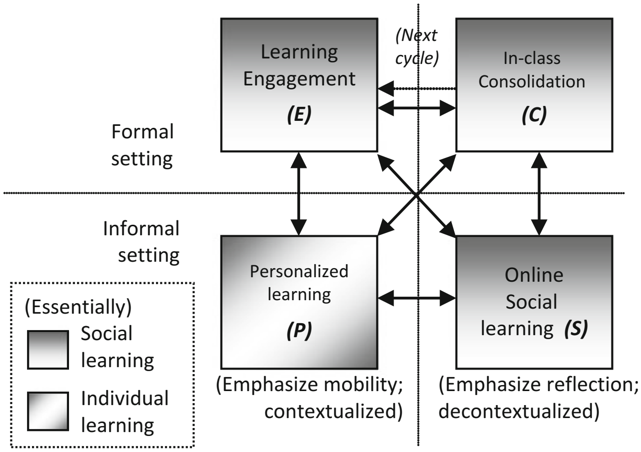

Fig. 1.4 The Facilitated Seamless Learning (FSL) framework (Adapted from: Wong 2013b)

activities (Kukulska-Hulme et al. 2009). Self-directed seamless learning, arguably the ultimate aim of the seamless learning approach, is however a tall order for learners who are more accustomed to the present transmissionist-dominated education system. Therefore, he envisaged the enactment of long-term facilitated-seamless learning where teachers engage learners in an ongoing enculturation process. The aim is to progressively transform their existing epistemological beliefs and methods of learning, and ultimately establishing and sustaining a culture of seamless learning (as explicated in the "Scoping and Re-scoping Seamless Learning" section).

Thus, a design framework for FSL processes was proposed, as shown in Fig. 1.4. Encompassing MSL1, MSL2, and MSL6 of 10D-MSL, the cyclical four-activity-type process consists of "learning *Engagement*" (E), "*Personalized* learning" (P), "online *Social* learning" (S), and "in-class *Consolidation*" (C). Nevertheless, the actual combination and sequence of the activities are customizable from cycle to cycle, as indicated by the bidirectional arrows. Apart from denoting the possible activity sequences, these arrows may also represent the spill-over effect of knowledge, skills, and learning resources as they flow from one activity to another, i.e., knowledge or skill learned, learning resources adopted or student artifacts generated during one activity may come into use in another activity (which may lead to MSL9 – knowledge synthesis). Apart from MSL1, MSL2, MSL6, and MSL9, a FSL process also reinforces MSL3, MSL4, and MSL10. MSL5, MSL7, and MSL8 are not explicitly represented in the framework as they belong to lower-level design details. In other relevant literature, Wong and his team demonstrated how the framework was employed to design seamless learning processes for "Move, Idioms!" (Wong et al. 2010) and MyCLOUD (Wong et al. 2012a) as well as to analyze the seamless-*ness* of existing learning process design in SEAMLESS project (Wong 2013b). In an earlier publication (Wong 2010), he also applied the framework to analyze a blended learning process (live lecture + blogging on PC) (Paulus et al. 2009) as a demonstration of how seamless learning could be accomplished without involving the mobile technology.

Nevertheless, the FSL framework is very much a learning design framework that delineates possible learning paths at the concrete activity level. To accomplish its target of enculturating self-directed seamless learners, what the framework lacks is a psychological dimension to establish and sustain the motivation and behaviors of seamless learning. This is a gap which might be able to be filled up by Sha's (Chap. 5) SRL model of MSL, which offers significant psychology-related guidelines in designing effective MSL environments.

A simpler framework known as "blended mobile learning model" is elicited by Hwang and Shih (Chap. 16) that prescribes a seamless learning flow comprising of traditional instruction, indoor mobile learning and outdoor mobile learning. In particular, "the two mobile learning modes help the students connect … what they have learned in the traditional instruction to the digital resources and real-world learning targets" (p. xx).

Knowledge Construction Through Seamless Learning

Indeed, from the perspective of (socio-)constructivism, the bridging of learning efforts across learning spaces can be re-conceptualized as the flow, transformations and syntheses of self- and socially constructed knowledge. This is perhaps the rationale behind the development of the next three process frameworks to be introduced – the trio shares the common affinity of foregrounding ongoing knowledge construction and improvement across learning spaces.

Chang and Chen (2007) put forward a knowledge building process based on diverse learning approaches as demonstrated in Fig. 1.5. Situated in a ubiquitous

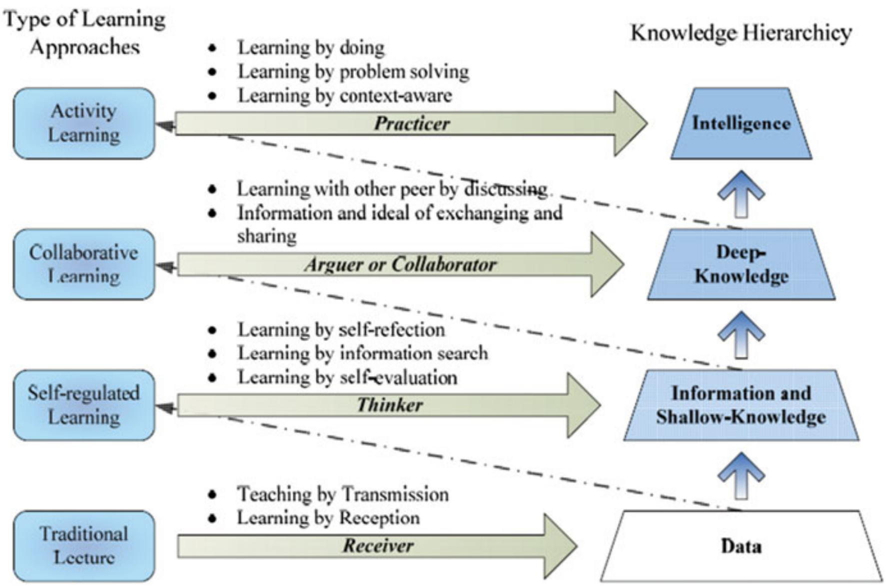

Fig. 1.5 Knowledge building process based on diverse learning approaches (Chang and Chen 2007)

learning grid (ULG) that was developed by the authors, this knowledge construction process underpins at least eight of the 10D-MSL dimensions (see Fig. 1.1), namely, MSL1 (formal and informal learning), MSL2 (e.g., incorporating both self-regulated learning and collaborative learning), MSL3 (e.g., from lecture halls to context-aware environments), MSL4 (across time), MSL5 (ubiquitous assess to learning resources via the ULG), MSL6 (physical + digital spaces), MSL8 (multiple learning tasks), MSL9 (multiple levels of abstraction of the knowledge), and MSL10 (four learning approaches). One may question the linearity of the process as prescribed in the diagram; however, the ULG system does support flexible executions of the learning approaches. Indeed, placing "activity learning" at the final stage of the knowledge construction process is inherently contradictory with the modern view of situated learning (Brown et al. 1989) where such activities should be carried out at much earlier stage to provide the much needed contextualized ingredients for self-reflection and collaborative knowledge improvement in the later stages.

In a related note, Zhang and Maesako (2009) defined a spiral process of learning and development situated in a four-quadrant space with "well- versus ill-structured knowledge" and "personal versus social learning" as the two axes (Fig. 1.6). Quadrants III and IV are the actual development levels for learners, while quadrants I and II are the potential development levels for learners. There is a zone of proximal development (Vygotsky 1978) between quadrants III and IV and quadrants I and II. The authors further pointed out that in the spiral of learning and development, a learner may jump steps or even progress in counterclockwise direction. This framework encompasses at least MSL2 (personal and social learning), MSL4 (across time), MSL8 (presentation, communication, construction, production and contribution), and MSL9 (knowledge synthesis).

Yet another "knowledge-centric" process framework was developed by Lin et al. (2008) to guide their own m-learning intervention design for an automotive practicum program of a vocational school. Albeit informed by the notion of

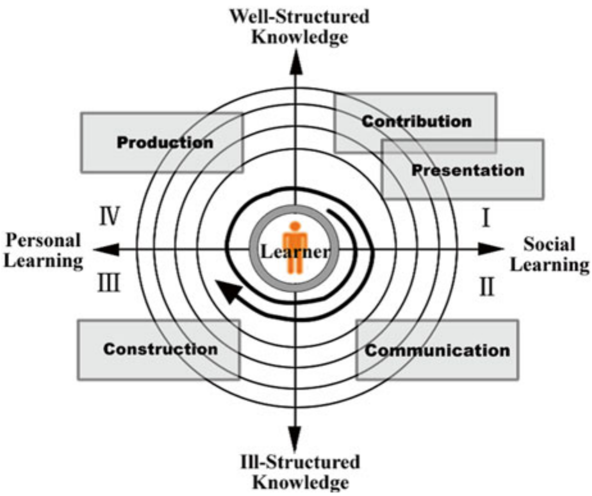

Fig. 1.6 A knowledge spiral-based ecosystem of learner development

scaffolding, the actual learning activities seem to be gearing toward transmissionism than constructivism to start with, where "teacher scaffolds" mainly refer to dissemination of (canonical) knowledge and information, followed by "removal of scaffolds" where students build on the teaching materials in their online discussions. The framework reinforces MSL4 (across time), MSL5 (ubiquitous access to the learning resources), MSL9 (knowledge synthesis), and MSL10 (multiple pedagogical models). The actual intervention design as reported in the paper further encompasses MSL1, MSL2, MSL3, and MSL7 (PDA + PC).

Designing "Seamless" Field Trips, Digital Storytelling, and Domain-Specific Learning Processes

So et al. (Chap. 16) attempted to fill the research gap of the lack of generalized design principles, strategies, and factors for educational field trips by distilling critical design elements that influence students' collaborative knowledge building during m-learning trails across multiple settings. Meanwhile, Nordmark and Milrad (Chap. 16) put forward a five-phase workflow for the enactment of cross-space mobile Digital Storytelling (mDS) processes. A more generic pedagogical framework is developed by Nicholas and Ng (Chap. 13) that stipulates the elements required in designing MSL pedagogies, namely, pedagogy, context and content, and key features that weave these elements together.

Two domain-specific design frameworks were also proposed – for science and language learning, respectively. Gillot et al. (2012) delineated the IBST (Inquiry-Based Science Teaching) approach to engage students in the following four activities: (1) authentic and problem-based learning activities which are ill-defined, (2) experiments and activities, (3) self-regulated learning activities where student autonomy is emphasized, and (4) discursive argumentation and communication with peers ("talking science"). Meanwhile, Wong, Chai, and Aw developed a generic Seamless Language Learning (SLL) framework rooted in second language acquisition theories and the theoretical underpinnings of task-based language learning, which is elaborated in Chap. 15. Similar to Wong, Chai, and Aw's approach of identifying various "seams" in typical language learning processes that need to be bridged, Kukulska-Hulme (Chap. 14) calls for using language itself (via mobile devices) as a tool (or "mediating artifact," in the context of DCog) to bridge formal and informal language learning.

In sum, this set of design frameworks arisen from various MSL studies were intended for concretizing seamless learning practices in diverse aspects – from redesigning the formal curriculum, emphasizing "bridging," foregrounding knowledge flow, fading out of teacher supports, to addressing the needs of domain-specific learning or outdoor learning trails. These frameworks offer guides or insights in MSL design to various levels of granularity. The choice of framework(s) largely depends on the learning goals being set. Among the eleven presented frameworks, FSL is the only one that is intended to reinforce enculturation of seamless learners and can be loosely mapped into the three knowledge construction-oriented frameworks and IBST. Indeed, one key issue that seamless learning researchers would need to reflect upon is that whether the goals of MSL enactments should go beyond content mastery and venture into the transformation of learning culture and epistemological beliefs, and the fostering of twenty-first century skills.

The Methodological Frameworks for MSL Research

An important consideration in studying MSL is to understand the enactments of learning activities unfolded in various situations. Studies that focus on examining episodic learning experiences, such as user satisfaction questionnaires and/or quasi-experimental constructs, are typically unable to provide comprehensive perspectives on learners' meaningful experiences across settings over time (Looi et al. 2010). In particular, since seamless learners are constantly on the move and much of their interactions happen in informal settings; this poses significant challenges to researchers for investigating and documenting emergent forms of learning and participation (Toh et al. 2013). In turn, Toh et al. (2013) and Wong et al. (2012a, b) reported two separate attempts to fill the gap by developing new research methodology or method specifically for MSL studies.

Toh et al. (2013) delineated a holistic methodological framework to guide full-fledged 1:1, 24×7 MSL studies (see Fig. 1.7). The framework is rooted in Rogoff's (1995) notion of "transformation of participation" which argues that children's sense-making endeavors are holistically intertwined with personal and cultural-institutional aspects that he/she is situated in. Using cultural activity (smartphone-mediated learning) as the unit of analysis, Rogoff (1995) suggested that "personal, interpersonal and cultural processes all constitute each other as they transform sociocultural activity" (p. 157).

The research approach that the framework has adopted is design ethnography. Other than describing and interpreting cultures (in their natural forms) akin to what the traditional ethnographers do, educational researchers could act as (instructional) design ethnographers (Barab et al. 2004) to create a conducive learning environment and study learners' learning experiences within the new ecology. Meanwhile, building on the framework of Hsi (2007) on studying the everyday activities of digital kids, Toh et al. (2013) expanded the data collection methods into four broad categories: cooperative inquiry (e.g., learner-generated multimedia that reflect their learning processes, interviews with learners in informal setting), participant observation, artifact repository, and quiet captures (installing software on learners' phones to unobtrusively capture the usage and experience data). The rich data collected could then be analyzed and triangulated through qualitative or grounded approaches. The privacy and ethical issues were also discussed in the paper.

In a related note, Wong et al. (2012b) placed their interest in the roles of artifacts in mediating seamless learning processes in "continually moving and re-constructed contexts" (Looi et al. 2013, p. 432), as informed by DCog and Vygotskian view of

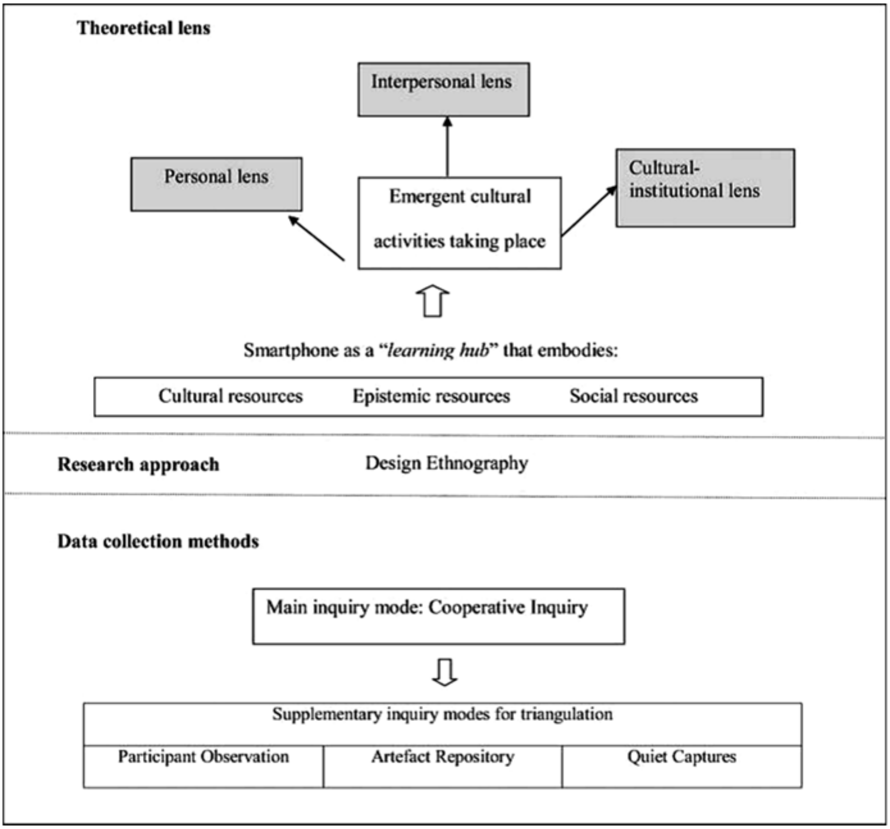

Fig. 1.7 Methodological framework for studying seamless learners (Toh et al. 2013)

"mediation by artifacts" (Stahl 2002). To unpack the learning processes of small-group cross-location MSL activities, they derived a visualization approach for descriptive analysis on the qualitative process data. In their analysis, they foregrounded the interplay between (socio-)cognitive activities and artifacts (including existing artifacts, digital and non-digital, that mediate the learning activities and the intermediate or "final" artifacts co-created by the learners) in various stages of the activities, and how a learner artifact generated in a previous stage could be transformed to an "input artifact" to the next stage and serve as a mediator for subsequent learning tasks. Such process data could then be represented as diagrams that unveil alternative paths that different individuals or groups of learners take to accomplish their learning tasks. Through the "artifact-oriented analysis," they highlighted the significance of fostering learners' habit-of-mind and skills in self-identifying, appropriating, and combining in-situ resources to mediate their learning activities across learning spaces, rather than always being "dictated" by resources that the teacher provides with fixed roles to play.

The Technological Frameworks for MSL Practices

Though seamless learning can be carried out without any ICT support, it is certainly the proliferation of mobile and cloud-based connectivity that has boosted the research, development, and even practice of this learning approach. The technological supports to MSL could come in different forms and levels of intensity, with similar aims of forming intellectual partnerships with individual or groups of seamless learners. Nevertheless, as most of the technological frameworks appear to be domain-specific, only six relatively generic frameworks are chosen to be elaborated in this section.

Learning Hub

"Learning hub" is a relatively abstract notion for the depiction of the role of technology in an individual seamless learner's hand. Within the context of MSL, Zhang et al. (2010) put forward an underpinning concept that the mobile device carried by a learner on a 24×7 basis integrates all the personal learning tools, resources, and self-created artifacts at one place, and a learner can foster his/her routine use of the learning hub to manage his/her own MSL. This affords him/her to seamlessly synthesize suitable learning resources that (s)he picked up along his/her ongoing learning journey to mediate the latest learning task (Wong et al. 2010). Simply put, a "learning hub" should be the nucleus of: (1) a suite of affordances to support learning activities and (2) the learner's learning history (including stored resources and self-created artifacts). Bachmair and Pachler (Chap. 3) offer a similar conceptualization of the indispensable role of personal mobile devices in bridging the formal and informal contexts, as they argue, "The interrelation of the two contexts is mediated by mobile devices and brings together the different options and resources inside and outside of the school. With their specific learning options, students and teachers generate a common context as a frame under construction, which combines actions and representational resources." (p. 16)

The conventional notion of 1:1, which is "one-device-or-more-per-learner" (Norris and Soloway 2002), considers the "division of labor" strategy where a learner may use mobile devices of different form factors for different learning tasks or in different learning contexts. Wong (2012) argued that the fast-rising cloud computing technology offers a viable (alternative) solution. A personal "learning hub" need not be associated with a particular device. Instead, it may exist as a learner account (that stores the learner history) on a cloud-based seamless learning platform (which also provides a suite of learning affordances). In this regard, he advocated the combination of a cloud-based "learning hub" account, a smartphone with 24×7 access, and additional notebook/desktop computers as an ideal technical setting for a personalized seamless learning environment (see Fig. 1.8).

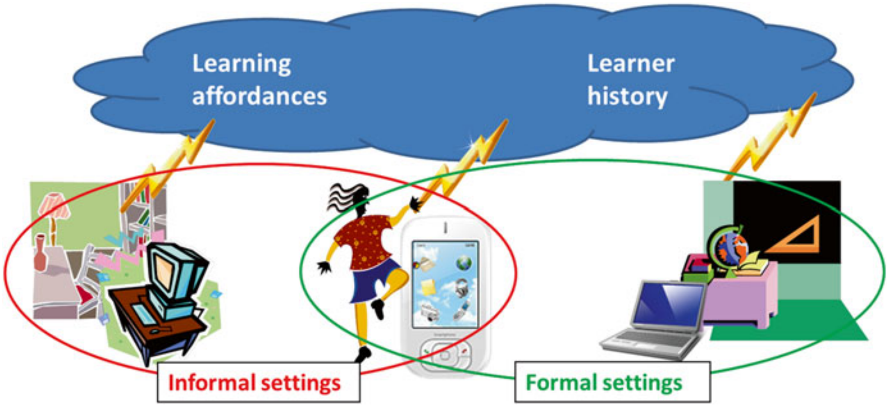

Fig. 1.8 The revised notion of "learning hub" for seamless learners

Congruent with the revised notion of "learning hub" is the following exposition made by Specht et al. (2012):

> The cloud offers a lot of potential to ensure access to important resources and information like learner profile data (e.g., prior knowledge, preferences), learning resources but also process related information like learning paths or current level for a specific learning goal. In combination with context filters and mobile applications the cloud can become the basis for a mobile personal learning environment (PLE) …The cloud unlocks a new potential for the development of seamless learning support that overcomes the existing problems of time and location and allows for a truly ubiquitous learning experience. (p. 28)

Indeed, such a visionary technological construct had been implemented in some of the earlier MSL studies even before the term "cloud computing" became trendy (e.g., Chang and Chen 2007; Khan and Zia 2007; Yang 2006). Many of the technological platforms reported in various chapters of this book can be mapped into this model. One of them is Mindergie (Kalz et al., Chap. 20), an augmented reality-based pervasive learning game to increase the environmental awareness and pro-environmental behavior at the workplace.

Frameworks to Support Development and Organization of Seamless Learning Resources

Five other frameworks which were developed with similar motivations of supporting learning resource development and sharing in u-learning and MSL environments are briefly presented next – please refer to the respective chapters for more details.

Inspired by the notion of "life-logging" enabled by wearable recording devices, Ogata, Uosaki, Li, Hou, and Mouri (Chap. 9) propose Ubiquitous Learning Log Object (ULLO), defined as a (perhaps geo-tagged) digital record of what a learner has learned with the support of ubiquitous technology in daily life. Aided by the technological platform of SCROLL (System for Capturing and Reminding of Learning Log), a learner can navigate and share with others his/her past ULLOs by augmented reality view, and receive system-generated personalized quizzes pertaining to the ULLOs. According to Milrad et al. (2013), a SCROLL-based seamless learning design may encompass MSL1, MSL2, MSL3, MSL4, MSL6, and MSL7 of 10D-MSL.

An alternative scheme known as learning cell is explicated by Yu and Yang (Chap. 8) for organizing and sharing learning resources within a seamless learning space. The authors coined the term "cell" to distinguish their scheme from the more established notion of learning objects. A learning cell is dynamic and neuron-like – it may evolve, perceive environments, adapt to terminals, and generate rich connections with its "fellow cells" and even with human users and form sociocognitive networks. Nonetheless, unlike ULLOs which are intentionally designed to be learner-generated, the "learning cell" research team had scoped the responsibilities of creating learning cells to instructors in their empirical studies at least till 2011; although they did not deny the potential of empowering learners in developing and sharing such resources within the learning community *(Yu, personal conversation, 27 October 2011)*.

Muyinda (Chap. 11) elicits the Mobile Learning Object Deployment and Utilization Framework (MoLODUF) as a 12-dimensional (or 12-step) process framework for developing and evaluating m-learning (and MSL in particular) applications. Similar to earlier conceptions of u-learning, the framework was developed with the assumption that "all the 'things' that contribute to its occurrence must be known in advance for the system to adapt to the context." (p. 1) Thus, this framework falls into the "adaptivity" camp of software engineering, an issue that will be explicated further in the later part of this section.

Specht (Chap. 7) puts forward the model of Ambient Information Channels (AICHE), which can be seen as a technical framework for distinguishing and structuring different components of contextual and seamless learning support. The model is comprised of four layers, namely, sensor layer, aggregation layer, control layer, and indicator layer. According to the chapter, embedded sensor technology builds the base layer of contextualized learning, which enables the aggregation of personal and environmental sensor data into feedback loops and adaptive educational systems. Meanwhile, the *control* layer building on this aggregated sensor information enables educational scripting for adapting to the current- or cross-contextual learning support. The *indicator* layer is where all visualizations and feedback for the user is described.

Finally, Tissenbaum and Slotta (Chap. 12) developed SAIL Smart Space (S3), an open source framework that coordinates complex pedagogical sequences, including dynamic sorting and grouping of students, and the delivery of materials based on emergent semantic connections. According to the authors, S3 facilitates "the physical space of classrooms or other learning environments to play a meaningful role within the learning design – either through locational mapping of pedagogical elements (e.g., where different locations are scripted to focus student interactions on different topics) or through orchestrational support (e.g., where physical elements of the space, like projected displays, help to guide or coordinate student movements, collaborations, or activities)" (p. 7).

Apart from the above-stated technological frameworks, there are a few other specific models that show the potential to be further generalized. These frameworks demonstrate diverse aspects of seamless learning that the technology could lend its helping hand to, such as adaptive PLEs (Bouzeghoub et al. 2011; El-Bishouty et al. 2010; Lai et al. 2007; Yang 2006), frameworks for orchestrating collaborative learning (Chen et al. 2008); Kohen-Vacs and Ronen, Chap. 23), frameworks for integrating multiple technologies or devices (Ahmad and Pinkwart 2012; Gillot et al. 2012), a framework for synergizing the learning ecology (Chang and Chen 2007), and a framework for classroom-based seamless learning (Li et al. 2009 – though confined within formal setting, it is seamless in some other dimensions). In particular, Kohen-Vacs and Ronen (Chap. 23) developed a technology that re-situates certain conventional forms of Computer-Supported Collaborative Learning (CSCL) scripts into cross-time, cross-space MSL settings.

Technology as "Enabler" or "Enhancer?" "Adaptivity" or "Adaptability?"

One relevant aspect is how the term "enable" appears in some of the scoping descriptions extracted to Table 1.1 – i.e., those from Chiu et al. (2008), Hwang et al. (2008), and Rogers and Price (2009). According to the descriptions, the three groups of authors contended that the technology is an obligatory element that makes seamless learning happen. On the contrary, Milrad et al. (2013) discussed about the distinction between technology as an *enhancer* or an *enabler* of seamless learning – on whether a seamless learning intervention or a specific seamless learning task is designed in the way that it can or cannot be carried out *without* the mediation of the ICT. A noteworthy observation is that for MSL designs that are essentially technology-enhanced (e.g., Anastopoulou et al. 2012; Hwang et al. 2011; Looi et al. 2010), "the physical and digital-based learning aspects of the activities are not as tightly coupled" (related to MSL6 of 10D-MSL) (Milrad et al. 2013, p. 106) in comparison with technology-*enabled* designs (e.g., Ogata et al. 2011; Sollervall and Milrad 2012). The latter types of design typically adopt context-aware/adaptive, augmented reality and/or geo-technology as their core ICT solutions. The technological frameworks cited in this section are in general meant for the development of predominantly technology-*enabled* interventions.

One last issue to expound here is the *adaptivity* and *adaptability* of technological solutions for MSL. Based on earlier definitions of the two notions in the contexts of software engineering and e-learning, systems that allow the user to change certain system parameters and adapt their behaviors accordingly are called adaptable, while those that adapt to the users based on the system's assumptions about user needs are known as adaptive (Oppermann 1994). The notion of adaptivity has now been extended to context adaptivity, i.e., differentiated learning resources or learning supports is adaptive to the particular learning space that a learner is situated in.

In principle, both adaptivity and adaptability features can be incorporated in a learning system at different levels of functionality and representation with varying effectiveness – and both notions form a spectrum representation of advanced learning systems (Oppermann et al. 1997). Mapping this spectrum to the MSL research, it seems that most of the MSL designs to date had been leaning toward either extreme of the spectrum. In particular, MSL designs with episodic or short-term interventions and heavy ubiquitous technology support tended to be more adaptivity-oriented. Notwithstanding, Song et al. (2012) cautioned that "such learning settings may result in the students' over-reliance on the system's recommendations while not being able to pick up the skills of self-identifying learning strategies or filtering of learning resources that are much needed for genuine autonomous learning" (p. 698). Attuning to their argument, the ever-improved adaptivity of the MSL technological solutions might help to reduce young and/or novice learners' cognitive load by almost always *adaptively* telling them what to do. However, in the long run, such adaptivity should not hinder learners' development of self-directed learning skills, i.e., their capability to self-adapt (in the sense of adaptability) their learning goals, learning paths, learning strategies, and choices of learning resources. Thus, the notion of adaptability here goes beyond "adaptability of the system" (in technological sense) but "adaptability of the learning experience" (in and out of technological support). The adaptivity and the (revised notion of) adaptability perhaps represent two different beliefs about learning (in particular, seamless learning) which however should not be seen as a dichotomy.

Conclusion: Bridging the Past and the Future

Looking back the past 8 years, though not a very well-modeled or well-theorized learning notion to start with, the "second life" of seamless learning has continued to show its strong potential and promise and gradually become a mature line of research and practice. Indeed, it was the "second life" of the learning notion that has substantially enriched and even re-defined its "first life." In this chapter, we have attempted to make deeper sense of seamless learning both within and beyond the context of TEL. Through examining the brief history of MSL studies from various vantage points (e.g., technology, pedagogy, context, ecology, psychology, knowledge construction, and the bridging efforts), it is further affirmative that seamless learning is much more than a special form of any other learning method. It is instead a learning approach at its own right and with its own niche – with "*bridging* of cross-space learning efforts" as the defining feature. The rich variety of expositions and frameworks reviewed in this chapter reflects the diverse perspectives and understanding of seamless learning in the field. The presented materials should not be seen as pieces of a jigsaw puzzle that we are trying to put together – as the metaphor of "jigsaw puzzle" would perhaps connote that there exists a canonical conception of seamless learning. Instead, seamless learning is an ever-evolving landscape that needs to be constantly refined, re-interpreted, and re-contextualized – so are lives, and the lifelong learning experiences of seamless learners.

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Chapter 2
Seamless Learning Despite Context

Mike Sharples

Abstract The chapter examines seamless learning, where the aim is to enable a continuous flow of meaning-making despite changes in the physical and social context. One way to achieve this is by inducing a flow state such that learners are so engaged in a mobile learning activity that they lose awareness of their surroundings. Mobile educational games may be one way to achieve such flow, but this is neither easy to achieve nor necessarily effective for learning. Another approach is to connect learning across contexts such as classroom and home. This approach requires careful orchestration of the learning, to enable the learning in one setting to be integrated into another. Seamless learning despite context is a fundamental skill that integrates self-directed learning, teacher guidance, and the support of a mobile technology toolkit.

Introduction

Context has become a central theme of research and development in mobile learning. Until now, work on contextual mobile learning has focused on how to deliver educational materials that are relevant to the learner's location, for example, in a museum (Lonsdale et al. 2004), a heritage site (Huizenga et al. 2009), or on a field trip (Verdejo et al. 2006). Or it has examined how to connect the learning that takes place in a classroom with learning outdoors (Vavoula et al. 2009; Adams et al. 2011). Or the research has examined context more broadly as a basis for design of mobile learning (Boyle and Ravenscroft 2012) and as a relationship between learners, technologies, and society (Traxler 2007). What none of these approaches to mobile learning has addressed is how to maintain a seamless continuity of learning despite the changing physical and social context.

Seamless learning can be defined as a continuity of the learning experience across contexts (Chan et al. 2006). This is best seen as an aspiration rather than a bundle of activities, technologies, and resources. In a 1996 paper introducing the concept, Kuh proposes that what were previously distinct experiences of learning

M. Sharples (✉)
Institute of Educational Technology, The Open University, Milton Keynes, UK
e-mail: mike.sharples@open.ac.uk

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(in-class and out-of-class; academic and non-academic; curricular and co-curricular; on-campus and off-campus) should be bound together so as to appear continuous (Kuh 1996). This learning may be intentional, such as when a teacher-led learning activity starts in a classroom, then continues as homework. It can also be accidental, for example, when an interesting piece of information from a newspaper or television programme sets off a learning journey that leads to exploration, discussion, or formal learning. Although the learner may be aware of context at any point in this journey and may benefit from contextual resources, the overall experience is of abstracting from specific times and locations. At its most successful, a learner may be able to experience a flow state of continual engagement with a topic (Csikszentmihalyi 1990) regardless of the passing time and changing surroundings.

This relates to the notion of autotelic (or self-motivating) learning (Moore 1959) in which the learner has an intrinsic desire to continue learning, such that the process of finding out is its own reward and the learner is motivated to accrete knowledge by exploring immediate ideas and surroundings. 'The most important attitude that can be formed is that of the desire to go on learning' (Dewey 1938, p. 48).

As Kuh indicates, such a self-motivated flow of learning rarely happens spontaneously; the individual learning experiences must be 'bound together to appear whole and continuous' (Kuh 1996, p. 136). Who will do the binding, and how? The responsibility could lie with the learner to initiate and maintain the flow of learning across contexts, with a teacher to guide and support the movement of learning from classroom to out-of-class, or with technology that enables learning activities to be initiated, suspended, and then rapidly restarted, or from a combination of these. In this chapter I shall explore the notion of seamless learning despite context, drawing on examples of previous mobile learning projects, from the perspectives of technology developer, learner, and teacher.

The Flow of Learning

The psychologist Mihaly Csikszentmihalyi has studied how people become absorbed into a flow of activity such that time and surroundings recede:

> You're right in the work, you lose your sense of time, you're completely enraptured, you're completely caught up in what you're doing…. There's no future or past, it's just an extended present in which you're making meaning… (Poet Mark Strand, quoted in Csikszentmihalyi 1996, p. 121).

A similar state of optimal flow can sometimes be achieved for learning, but such a state of absorption, engagement, fulfilment, and progress is at odds with a typical classroom where the task is set by the teacher, there are continual distractions, and time is compartmentalised into 40 min periods. Figure 2.1 shows the nearest to a classroom state of flow. The children are working at laptop computers with touch screens and the task for each child is to write a summary of books read over the previous week, then to draw a picture on the computer screen that illustrates the

Fig. 2.1 Children in a Taiwan elementary school absorbed in a writing and drawing activity on mobile devices

book. The summaries are then stored on the school intranet and the children can read and rate each other's work. When a group of academic visitors arrived and walked round the classroom taking photos, the children barely glanced up and none spoke. Such silent focus on the task is, perhaps, more a consequence of the Taiwan education system than the personal technology; however, the devices provide both a medium of expression and a means to coordinate the learning activity.

Csikszentmihalyi (1996) proposed nine indicators of a flow state that are equally applicable to the flow of learning:

– There are clear goals every step of the way.
– There is immediate feedback to one's actions.
– There is a balance between challenges and skills.
– Action and awareness are merged.
– Distractions are excluded from consciousness.
– There is no worry of failure.
– Self-consciousness disappears.
– The sense of time becomes distorted.
– The activity becomes 'autotelic' (it is done for personal satisfaction).

In a flow state, the student is engaged in an overarching context where they are impervious to physical, temporal, social or technological changes. Designers of educational technology need to understand how learners enter such a flow state, how it can be maintained despite the changing setting, and whether it can contribute to effective learning.

Flow and Computer Games

As regards mobile technology, the obvious parallel is with computer games. These are deliberately designed to promote a state of flow and continuous engagement, by setting clear goals, providing immediate feedback, balancing challenge and skills, merging action and awareness, limiting the effects of failure and suppressing distraction. In his classic work on what makes computer games fun to learn, Malone (1980) refers to Csikszentmihalyi in analysing the intrinsically motivating aspects of computer games.

Since then, designers of learning technology have attempted to 'gamify' educational software, by engineering challenge, curiosity, and fantasy (Malone 1980) and by deploying the mechanics of gameplay to enhance learning (Habgood and Ainsworth 2011; Reeve 2012). When such game-based learning is implemented on mobile devices, the aim is that people of all ages might experience a seamless flow of learning across space as well as time.

This is one vision of seamless learning: people so engaged in a mobile learning activity that they lose awareness of their surroundings. Yet this is neither easy to achieve nor necessarily desirable in practice. The easiest way to create a flow of mobile learning is through a narrative such as an educational video or podcast. A study by Evans (2008) indicated that university students find podcasts to be more engaging and effective than textbooks for revision, but there is a lack of evidence that they improve initial learning (Heilesen 2010). The same is true for 'flipped classrooms' where students can watch video lectures, at home or on mobile devices, and then work on assignments, labs, and tests in class. While the home or mobile activities may be engaging, they deliver lectures by another medium and 'an overwhelming body of research shows that students do not learn effectively from lectures' (Twigg 2004). The more that mobile lecture delivery is modified to try and improve learning effectiveness, for example, by allowing students to stop and rewind the video, or to take notes, the less the learning is continuous and uninterrupted. There is no evidence that providing a continual flow of learning material will result in effective learning, and the learner should not just stop and start the flow of learning but control and guide it.

Another route to seamless learning is to make interactivity an intrinsic part of the educational experience so that the learning content is integrated with the mechanics of the gameplay (Habgood and Ainsworth 2011). In Habgood's game of Zombie Division, children learn the mathematics of dividing numbers through a video game where zombies appear with numbers on their chests and the player must choose an appropriate weapon to 'divide' the zombies (Fig. 2.2). For example, a zombie carrying the number 12 can be killed with a weapon of 2, 3, 4, or 6 blades. In one of the few comparative studies of game-based learning, Habgood found that the version of the game where flow and reward were integrated with the teaching resulted in significantly greater learning gains than a version where the teaching content and the gameplay were separated. Although Zombie division was developed for desktop devices, the same principles can be applied to mobile educational games. Designing such a 'flow-learning' game is not simple: Habgood is a professional computer game designer and the work was carried out over the 3 years of a PhD.

Fig. 2.2 Screenshot from Zombie Division (Habgood 2007)

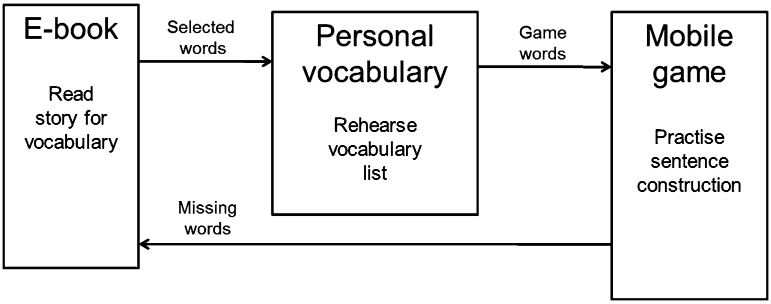

Fig. 2.3 The flow of activity in Elmo between e-book and game

Another attempt to create a seamless flow of engagement between mobile learning and gaming was the Elmo project. It objective was to help non-native speakers of English to acquire vocabulary through incidental learning rather than direct instruction. Figure 2.3 shows the flow of activity. Each page of an illustrated electronic book displays highlighted words matched to the learner's reading level.

The learner can click on words to get further information and practice, such as hearing a pronunciation or drawing a picture of the word. Each of these selected words is stored in the learner's personal vocabulary list. At any point the learner can switch to a visual game where the aim is to solve puzzles by forming sentences in English to guide a cartoon dog (Fig. 2.4). The puzzles are related to the content of

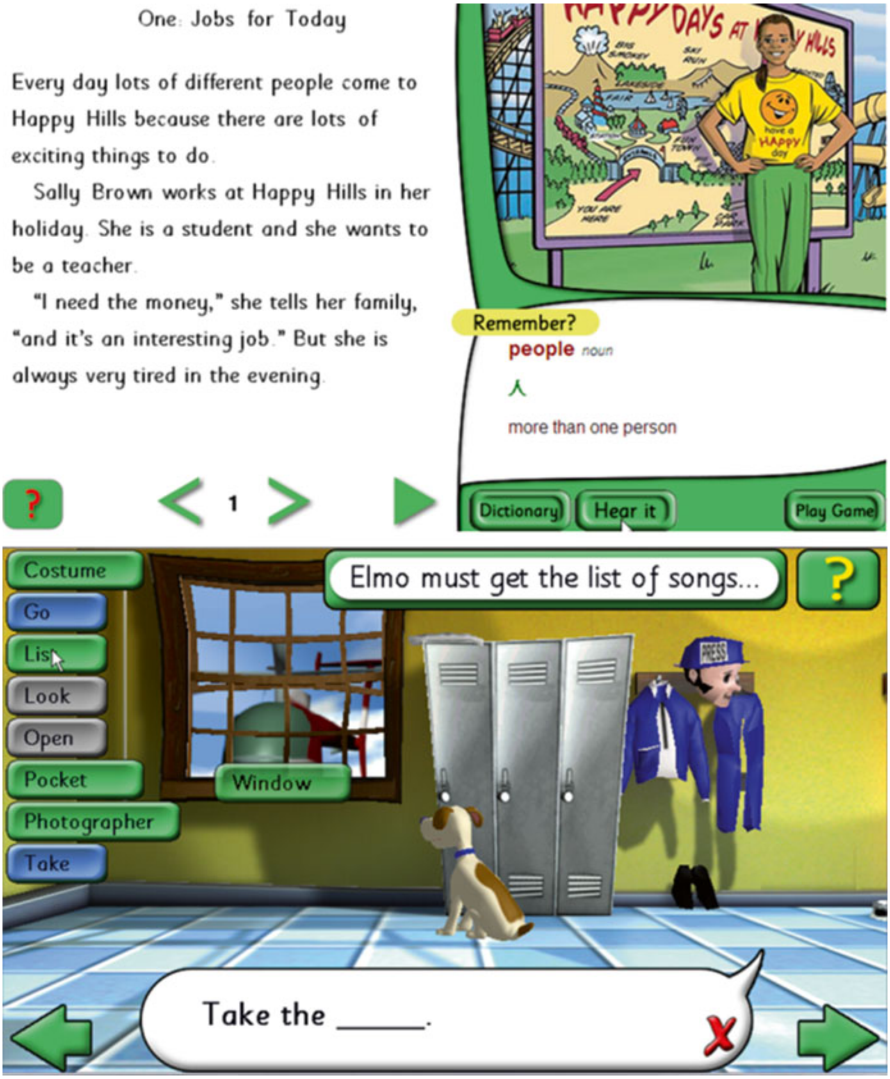

Fig. 2.4 Screenshots from the Elmo e-book and game

the book and only words previously collected by reading the book can be used to guide the cartoon dog. When the learner reaches an impasse in the game, she can switch to reading the book and collect more words. When the learner wants to practise using the vocabulary, she can switch to playing the game. An application for Android phones based on the Elmo approach of adaptive vocabulary learning from e-books linked to game practice (though of individual words rather than sentence construction) is marketed in Japan as Tadoku Academy (http://www.facebook.com/tadoku.academy).

For the learner, there are clear benefits to maintaining a flow of learning on mobile devices despite changes in context. However, the technical and educational issues are raised to a higher level than with contextual mobile learning on a single device. In flow learning, the technical challenge is to maintain a continuity of learning experience across changing devices, times, locations, and social interactions. This is being addressed through cloud computing, where the learning software application is stored and managed on a remote server, with the learner having access over mobile networks on a variety of devices. Software development environments for cloud computing, such as the Google App Engine (Google 2013), enable web applications to be run across multiple servers and accessed on multiple machines.

The educational challenge is to enable a seamless flow of activity that supports satisfying and effective learning. Yet, while there is some evidence that flow induces satisfaction, there is no clear evidence of a relation between flow and learning effectiveness. Hassell and colleagues (2012) studied learning in the virtual world of Second Life. They found that those students who experienced higher levels of flow and 'presence' (immersion in the game world) were more satisfied, but not necessarily more effective as measured by a quiz on the learning content at the start and end of the game.

Perhaps, as Pelletier (2009) concludes from her study of children designing their own computer games, the most effective learning is not *about* games or their content, but comes *through* a continuing process of designing and playing game-like activities. For her PhD studies, Roy et al. (2009) ran game design workshops with peer educators in the 'males having sex with males' community in Kolkata, India, to develop a collaborative game on mobile phones based on simulated challenges and role-play scenarios. The mobile technology enabled the participants to engage with a shared educational game despite their differences in background, ability, and location. But the learning did not come primarily from engaging with the game content, but through the design process and from discovering that mobile phones and text messaging could be a means to keep in touch and share work experience across contexts.

We need to find new ways to enable learners, individually and collectively, to follow their learning desires and to support them in a continued process of meaning-making, by providing appropriate resources and tools whenever they are needed, by allowing a learning activity to be suspended and resumed, and by harnessing the power of social interaction across contexts.

Connected Learning

Another approach to seamless learning despite context is to connect learning across locations and settings. This is not an alternative to flow learning, but can be seen as a way to supplement it, by offering opportunities to link together activities that have occurred at different times and places. As people move through time and space, only some points will be relevant to their learning goals; so these should be connected while suppressing the less relevant intervening activities. A familiar example is school homework, where the teacher sets a task in the classroom and expects it to be completed at home, with the results brought back into the classroom for marking. What happens in between is irrelevant. For homework, it is sufficient to have instructions to carry home and a written assignment to take back to class.

With mobile technology, the opportunities for connected learning can be extended from written tasks to exploratory and inquiry-based learning. By using a mobile device (such as a smartphone or tablet) as a scientific toolkit, the learner can perform experiments or collect information in one location that can be analysed, shared, or presented in another. Two mobile learning projects illustrate this approach.

The MyArtSpace project (Vavoula et al. 2009) addressed the problem of how to connect informal learning on a school visit to a museum or gallery with teacher-led learning in the classroom. The project engaged 3,000 children and 3 museums over 13 months. In a pre-visit lesson, the teacher introduces the museum and proposes or negotiates a question to guide the visit for each child. For example, on a visit to the D-Day Museum in Portsmouth (which commemorates the Allied landings in the Second World War), a question might be 'Were the landings a success or a failure?' The children visit the museum and collect evidence using a pre-loaded application on a mobile phone. They can hear pre-recorded audio presentations of exhibits, take photos, record commentaries, and make notes. These are automatically sent by phone connection to the child's personal webspace. Then, in a subsequent classroom activity, the children individually or in groups create presentations that address the guiding question.

The Personal Inquiry project (Anastopoulou et al. 2012) had a similar pedagogy of inquiry-based learning within and outside the classroom, with the difference that each child was loaned a personal netbook computer with software to guide the classroom and outdoor learning. In a typical investigation, children addressed the question 'Is my diet healthy?' by compiling a photo diary of the food they ate over 3 days, with the inquiry toolkit assisting them to calculate the nutritional content of the meal and relate it to typical requirements for children of their age.

Both projects were successful in extending school learning outside the classroom. A basic measure of success for MyArtSpace was that the average time the students spent engaging with the museum was 90 min compared to 20 min for a typical school visit. The Personal Inquiry project enabled children to carry out an entire inquiry cycle of forming a question, collecting real data, and sharing and presenting results.

From the learner's perspective, the main difference was that the children used the same device within and outside the classroom for personal inquiry, whereas for MyArtSpace they were loaned smartphones in the museum and the data were sent to a webspace that they could access by password. Each had its advantages. Having a personal webspace meant that the MyArtSpace children could view the results of their museum trip at home and share them with parents. By contrast, the children in Personal Inquiry could carry an inquiry toolkit with them between school, home, and outdoors. Recent developments in tablet technology and cloud computing now offer the best of both, in that a learner can carry a device that acts as a scientific toolkit (with camera, voice recorder, notebook, position locator, tilt sensor, compass, accelerometer, etc.) connected by mobile network to a personal data store and webspace.

A difficulty for both approaches is in connecting the outside activities back into a classroom lesson. The learner must rapidly re-establish understanding that has been gained in an outside context in the very different setting of a classroom lesson. During the MyArtSpace project, children sometimes found it difficult to remember where and why they had taken pictures or how these related to the guiding question. They needed support to recall one context (the museum) within the framing of another (the classroom). This could either be done by de-contextualising the activity, for example, by asking children to collect data that are analysed by their intrinsic properties (as in the food diary where the data related to the content of the meal, not where it was eaten), or by providing additional technology (such as GPS location or an annotation facility) to enrich the results with additional contextual information.

Unlike a typical homework assignment, the results of the outside learning are not presented to the teacher for marking but are used as the basis of a classroom activity. The teacher must conduct a lesson around whatever findings the children bring at the start of the lesson. This disciplined improvisation (Sawyer 2004) can be demanding of a teacher, but can also be a source of productive learning as the teacher explores connections between the brought data and the inquiry question, or extracts general principles from the results.

The learning can come from unexpected results: for example, in an inquiry to study the effect of noise on bird feeding in the school playground, the children collected data that confounded their predictions that birds would eat more food in quiet areas of the grounds. The children then set up a webcam in the grounds and found that food was being eaten by a greedy pigeon that was unaffected by noise. Learning can also arise from failure. In MyArtSpace, children typically collected so many pictures and recordings that they were unable to organise and present them back in the classroom. The teacher was able to use this as an opportunity to discuss the importance of being selective in collecting data.

Orchestration of Learning

The examples of disciplined improvisation in the previous section raise two important issues related to seamless learning: the additional burden on the teacher and the need to structure and support a continuity of learning despite the changing context. In the Taiwan 1:1 classroom, shown in Fig. 2.1, the learning was tightly constrained so that each child was performing a similar, well-understood, task in a familiar setting, with each child operating an individual computer programmed to support a specific task. The primary role of the teacher was to supervise the flow of activity, occasionally answering a child's query. Figure 2.5 shows the flow of activity and communication between teacher, students, and technologies.

As the context of learning becomes less predictable and constrained, for example, in a classroom where each child is equipped with a tablet computer for all lessons, then there is an increasing need for the teacher to manage both the lesson activity and the technology. If the technologies and the activities span time and location,

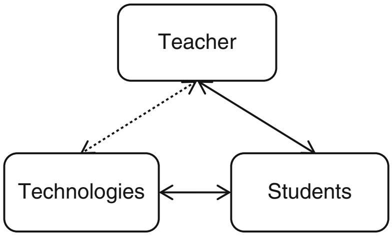

Fig. 2.5 Flow of activity and communications in a constrained 1:1 classroom

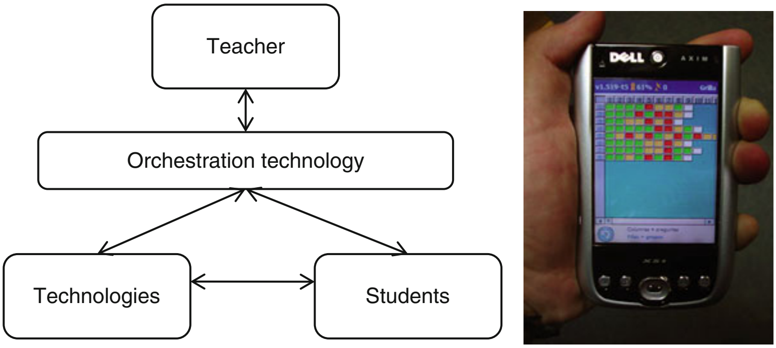

Fig. 2.6 Orchestration technology in the classroom (Picture from Nussbaum et al. 2010)

there is even more need for effective management. The metaphor of 'orchestration' has been proposed to describe the design and management of a learning activity by a teacher in real time, assisted by personal technology (see Dillenbourg and Jermann (2010) for an overview).

Both the MyArtSpace and Personal Inquiry projects identified orchestration of learning as the central issue in supporting a pedagogy of inquiry-based learning that encompassed teacher-initiated inquiry in the classroom, learner-managed investigation at home or outdoors supported by mobile devices, and group activity back in the classroom to synthesise and share findings. Both projects identified the issue of managing a seamless transition from classroom to home or outdoors and back again, by describing clearly the task to be performed and then integrating the results of the out-of-class activity back into a lesson.

Figure 2.6 shows one way of orchestrating learning on mobile devices. The teacher is equipped with technology to view and manage the flow of activity. For example, the Eduinnova system developed by Nussbaum and colleagues provides a handheld 'dashboard' (Fig. 2.6, right) for the teacher to see the activities (columns) performed by the students (rows) as the progress over time, with green marking successful completion, amber showing repeated attempts, and red an incorrect answer. The teacher can also set new tasks and record marks using the handheld software. While this 'fly by wire' teaching classroom may work for some well-structured classroom activity, the reality is generally more complicated, with the teacher also engaged in direct discussion with the students, the students talking with

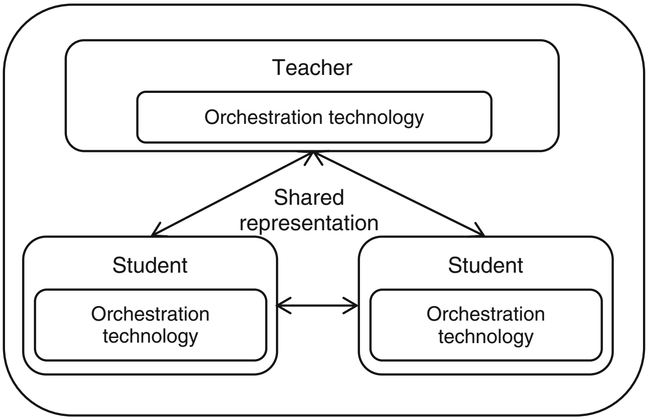

Fig. 2.7 Orchestration technology for seamless learning

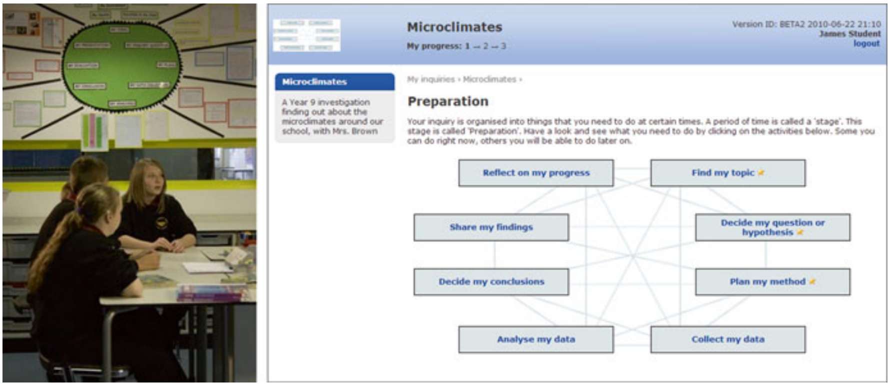

Fig. 2.8 Representation of the inquiry process in the classroom and on the nQuire screen

each other, and the teacher intervening to solve technical problems. Take this outside the classroom, for example, on a museum visit where the students are distributed around the building and the teacher-managed orchestration may become complex and fraught.

An alternative is to share the control more evenly amongst teacher, learner, and technology. Figure 2.7 shows the orchestration for the Personal Inquiry project. The teacher and the students have identical netbook computers, running the nQuire inquiry learning software, with the teacher's device connected to the classroom smartboard. The aim is to engineer a seamless transition not only across contexts but also forms of orchestration (Anastopoulou and Sharples 2012).

The project developed a shared representation of the inquiry process that functions in the classroom as a guide to science inquiry (Fig. 2.8 shows it used as a classroom wall display) and on the nQuire screen as links to manage the series of inquiry science activities.

The nQuire software works as a personal inquiry management system. Within the classroom, the teacher orchestrates the learning, by introducing a theme then proposing or negotiating with the children the specific questions to explore. For example, within the theme of Healthy Eating, an inquiry question might be ‘Is my daily diet healthy?’

The teacher then passes control to the software, which forms the children into groups and assists them in planning their method of investigation. In class, the groups of children form a collective plan and decide on the method of investigation. Then, the learning continues outside class, orchestrated by the nQuire software. Each child individually interacts with the software to carry out the activity and collect data. In the example of the healthy eating inquiry, this consisted of each child taking photographs of every meal over 3 days, uploading each photograph to nQuire, selecting the food items from a simple pre-prepared list (e.g. ‘1 portion cereal’, ‘1 portion milk’), and viewing a bar chart of the nutritional content of fat, carbohydrate, vitamins, etc. Lastly, back in the classroom, the software synchronises the data and children work in groups to compare the results with each other and with the recommended nutrition levels for children of their age. The teacher resumes orchestration of the classroom group activity.

The software does not fix the order of tasks and the children can move backwards and forwards through the inquiry process, to view future activities and to revisit previous ones, such as revising the inquiry question. It manages a continuity of learning across contexts and handover of control from teacher, to groups, to individuals, and then back to groups and the teacher. It also connects and constrains activities across time; for example, the ‘decide my conclusions’ activity re-visits the initial questions and asks the learners to answer them based on their analysis of data. The aim is to enable a seamless handover of learning management from the teacher to the student-with-computer, and also to support a seamless flow of control across activities.

Software alone will not solve the difficult problems of how to maintain a seamless flow of learning despite changes in context and control. The children need to be carefully prepared for individual work outside the class, so that they do not go ‘off track’ (metaphorically or literally) and engage in excessive collecting or irrelevant activity. The teacher has an additional burden not only of managing a process of open inquiry but also of orchestrating a demanding classroom lesson involving disciplined improvisation in order to synthesise the findings and draw meaningful conclusions. Finding an appropriate balance of orchestration between learners, teacher, and technology is a fundamental element of the new ecology of mobile learning that bridges formal and informal settings.

Conclusions

Taking a broad view, Wong and Looi (2012) propose that seamless learning is more than a set of novel educational practices; it requires a change in the culture of education to incorporate mobile learning into the curriculum and to equip children with the meta-cognitive abilities that allow them to relate learning that occurs as part of daily life to the knowledge and skills they have gained as part of formal education. The ultimate aim of seamless learning, Wong and Looi propose, is to enable people to engage in productive self-regulated learning that spans times, locations, devices, and tasks.

It is undoubtedly valuable that children should learn at an early age that learning can occur anywhere and that knowledge formed in one setting can be applied in another. For this to happen, they need to learn when knowledge is contextualised – bound to the place, time, or social settings where it occurred – and when it can be abstracted to form general principles that can be applied elsewhere. They also require conceptual and technical tools, for sense-making and reflection, to continue the flow of learning as they move through time and place. These abilities need skill and practice to develop, so the teacher will remain essential in helping young people to make deep sense of the world despite the changing context.

Take, for example, the Healthy Eating project activity that the children carried out as part of the Personal Inquiry project. The teacher had an essential role in framing the investigation, elaborating the concept of healthy eating, introducing the elements of diet such as vitamins, protein, fat, and carbohydrates, and showing how the food intake for a day can be related to typical levels for a child. All these teacher-led activities prepare the children for seamless learning despite context, so that as they keep daily food diaries they know *how*, *why*, and *where* they should be carrying out the activity (e.g. how to recognise nutrition content from food labels despite differences in packaging) and can make sense of their findings. In the subsequent classroom lesson, the teacher has a role in helping to integrate and interpret their findings despite the differing contexts in which they collected the information. Each child is using the mobile technology to make sense of a fundamental concept across changes in context, and the teacher offers help and support to frame, regulate, and integrate the learning. Seamless learning despite context is a fundamental skill that can be best gained through a combination of exploratory sense-making, self-regulation, mobile technologies for data collection and visualisation, and a teacher trained in methods of inquiry-led learning.

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Chapter 3
Framing Ubiquitous Mobility Educationally: Mobile Devices and Context-Aware Learning

Ben Bachmair and Norbert Pachler

Abstract In the context of the normalisation of mobile devices, this chapter argues that mobile devices and the artefacts accessed through and created with them should be viewed as important cultural resources and, therefore, constitute valid resources for learning. In line with ongoing transformations around the individualisation of society and convergent mobility of technology, mobile devices, including tablet computers, have become widespread beyond professional target groups and have started to penetrate the everyday lives of wide segments of the population. These devices are increasingly assuming and being ascribed cultural functions which transgress everyday life; multimodal, convergent mobile devices have become an integral part of life courses. For the moment learning is not in the foreground of these cultural functions nor are they accepted yet in formal learning and its institutions.

The chapter discusses the function of mobile devices as cultural resources from the perspective of Bourdieu's concept of cultural capital in order to define their role for learning. In particular, use is made of Bourdieu's concept of habitus as incorporated cultural resources, which coincides with the use of mobile devices but is in conflict with institutionalised learning resources. We propose 'recognition' as an important practical as well as theoretical endeavour to re-conciliate institutionalised modes of learning with mobile devices. An example of a mobile portfolio is used to clarify the proposed 'recognition'. In addition, we analyse the societal mobile complex in which mobile devices have become part of everyday life and have reached the level of relevant and legitimate cultural resources. We apply a widened structuration model with the intersecting categories of socio-cultural structures, agency and cultural practices for identifying the values of mobile devices for informal and formal learning. We consider the socio-cultural structure of user-generated contexts in two strands, namely, as learning contexts and contexts for personal development. We discuss the interrelationship of contexts and mobile devices within the conceptual educational tradition of learning. Through an example we link our theoretical argumentation to the learning practices of young people.

B. Bachmair • N. Pachler (✉)
Institute of Education, University of London, London, UK
e-mail: Ben.Bachmair@t-online.de; N.Pachler@ioe.ac.uk

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Mobile Devices as Representational Resources

Outside of school, mobile devices are in the hands of young people and students across the world. Mobile devices ranging from smartphones and tablets to music players and game consoles are among the main resources of everyday life. What we call *resource*, i.e. the devices integral to users' media habits, is equivalent to what in 1964 Marshall McLuhan (2001, pp. 6f.) called 'extensions of man'. Of course, he talked about more traditional media such as television. The question arises whether we should be framing mobile devices as media. In our estimation they have 'outgrown' such definitional approaches: They are resources, artefacts and activities of and for representation and meaning making. The normalisation and the 'everyday-ness' of mobile devices, their inclusion in work situations and the public sphere, contain and carry specific cultural 'messages', which is how McLuhan (p. 7) metaphorically described the affordance of media to human beings and how he saw them acting on and in the world. The actual metaphor for 'mobile human extensions' is ubiquity, always and everywhere. Ubiquity derives from mobile devices being part of media convergence through the Internet. Furthermore, ubiquity is an extension of the socio-cultural dynamic of individualisation, which is also a consumptive disposition towards commodities, services, sites and situations as well as a way of dealing individually with social, communicative, economic and/or ecological risk in one's personal life course (see also Pachler et al. 2010a).

At the risk of oversimplification, we offer two examples from the everyday life world here by way of exemplification. In them we focus on representation through the use of digital still and moving images. The first example involves an around 3-year-old boy using the photo function of a smartphone to take close-up images of an inflated balloon for further exploration and 'forensic' examination of the surface structure using the zoom function. Lack of linguistic resources as a meditational tool is compensated for by use of augmented visualisation. The second example involves the same child 2 years on, now some 5 years old, repeatedly viewing YouTube video recordings on a tablet produced and uploaded by mostly adult males of themselves playing (computer) games. In part, viewing the videos is a compensatory mechanism for the boy due to the lack of availability of the game in question on the tablet; to a large extent, however, it is an instantiation of learning governed by his criteria of personal relevance in an attempt, again commensurate with his linguistic repertoire - he has just started to learn to read - by watching more advanced players and by listening to the commentary in which the players explain and reflect on their actions aloud (not aimed at 5 year olds) to generate his own developmental context as a game player. These vignettes show how even young children are able to use mobile devices as meaningful representational resource for purposes of meaning making. We have no doubt that the child in question is not unique in this respect.

McLuhan's anthropologically orientated metaphor of media as 'extension of man' for us is supported, among others, by social semiotics, especially 'Gunther Kress' theory of multimodality (Kress 2010). From this perspective, mobile devices can be viewed as cultural resources for representation with the basic affordance of contributing to meaning making. The cultural frame for the 'mobile' mediation of meaning making relates to ubiquity and a consumptive disposition towards commodities, services, sites, etc. Our theoretical orientation towards mobile devices as cultural resources can be seen to offer analytical potential to discuss their function for meaning making in diverse contexts. Despite all its differences, there is a constitutive communality between acting in everyday life and learning in school. Both depend on cultural resources for meaning making. In what we elsewhere call the 'mobile complex' (see Pachler et al. 2010a) spatial frames have become situational and contextual frames for meaning making and differ with regard to some essential features.

For Traxler (2010), the change of traditional definition of space is in the foreground of ubiquitous mobiles:

> Mobile devices demolish the need to tie particular activities to particular places or particular times. They reconfigure relationships between public and private spaces, and the ways in which these relationships are penetrated by virtual spaces. Virtual communities and discussions were previously mediated by static networked PCs in dedicated times, places and spaces. Now, mobiles propel these communities and discussions into physical public and private spaces, forcing changes and adjustments to all three as we learn to manage a more fluid environment. (p. 59)

Following this line of argumentation, we propose to consider the affiliation of mobile devices to *contexts* as a successor to the traditional definition of space in which and in relation to which humans act. We are influenced in our perspective on user-generated contexts by Dourish's proposal (2004) from the field of computer sciences who conceptualises context as an interactional rather than a representational problem:

> First, rather than considering context to be information, it instead argues that contextuality is a relational property that holds between objects or activities. It is not simply the case that something is or is not context; rather, it may or may not be contextually relevant to some particular activity.
>
> Second, rather than considering that context can be delineated and defined in advance, the alternative view argues that the scope of contextual features is defined dynamically.
>
> Third, rather than considering that context is stable, it instead argues that context is particular to each occasion of activity or action. Context is an occasioned property, relevant to particular settings, particular instances of action, and particular parties to that action.
>
> Fourth, rather than taking context and content to be two separable entities, it instead argues that context arises from the activity. Context isn't just 'there,' but is actively produced, maintained and enacted in the course of the activity at hand. (p. 23)

If we define context in respect of ubiquitous mobility, we need to take into account that 'space' is under reconstruction. More theoretically speaking, the 'space' in which young people take photos, in and to which they send text messages, which they investigate through specialised apps, such 'spaces' are losing their traditional forms and functions. They are becoming *contextual* environments. One feature element in this transformation is the provisional character of spaces as *contextual* environments, which Kress describes (2010) thus:

> Contemporary social conditions in Anglophone and Western European societies are markedly different to those of some four decades ago. Stability – even though that had only ever been

> relative – has given way to instability; homogeneity has given way to often radical diversity; permanence has given way to provisionality, a condition in which crucial characteristics of the environments of communication may vary from one moment to the next. (p. 171)

From this perspective, spatial 'mobile' environments are contexts and we define context here as a frame under construction for optional combinations of actions, representational resources including media and literacy, virtual and local sites or social sites such as socio-cultural milieus.

When we speak about mobile devices, we consider them as representational resources within or across contexts. In this sense, mobile devices in everyday life as well within learning in informal contexts are representational sources within conversational processes.

With this definition of mobile devices as representational resources within or across contexts, it is possible to return to the statement in the introductory sentence: 'outside of school, mobile devices are in the hands of young people and students across the world'. The school as mobile-free area is an institutionally defined context with representational resources for learning, which is connected by the students to their everyday life contexts with their own and context-specific representational resources. It is up to students to combine the traditional context of the formal learning environment with their life contexts. This may happen by taking the representational resources of the school outside, e.g. in the form of school-owned tablets, or by bringing in the representational resources of everyday life into the school, e.g. by using personal mobile devices for school learning. The ubiquitous nature of the mobile phone enhances the transgression of these contexts with their relevant representational resources. As we know, in the everyday life context of students, mobile devices are highly relevant. Almost all students aged 12 and over own a mobile phone/smartphone (see Medienpädagogischer Forschungsverbund Südwest JIM-Studie 2012, p. 52).

It seems that the *mobile* life contexts outside of school are not very different in respect to gender and social stratification. A big gap exists between everyday life contexts, which have become amalgamated with different versions of mobile devices, and traditional and institutionally defined learning inside of school. Whether mobile devices and the artefacts accessed through and created with them constitute adequate resources for learning within a school context is still an unresolved question as far as many teachers and schools are concerned. Tablets as members of the computer family are more readily recognized as an adequate resource than mobile phones or smartphones, which are rooted in conversation practices of everyday life.

In the process of implementing the small handheld devices prevalent in everyday life, i.e. mobile phones and smartphones, as resources for institutionally recognised learning, we have to discuss the relation of learning contexts and mobile phones as representational resources.

From the perspective of contexts as frames under construction with or without mobile devices as representational resources we view *context-aware learning* as an option to introduce mobile learning into formal educational institutions for the purpose of teaching and learning. Traxler (2010) offers a helpful perspective for a culturally aware way to achieving this implementation of mobile devices:

> Interaction with desktop computer takes place in a bubble, in dedicated times and places where the learner has their back to the rest of world for a substantially and probably planned episode. (p. 59)

That means the desktop computer is a resource, which defines contexts in a way that correlates to the definition of the teaching context of schools: standardised, fixed, timetabled, productivity-orientated, etc. There are no real elements of provisionality and contingency, which characterise mobile phones and the life contexts they originate in. Tablets seem to fit with the *desktop* context, which appears as less provisional and contingent and more appropriate to the requirements of school as an institution for learning.

Context-Aware and Situated Mobile Learning

Our perspective on mobile devices as representational resources for learning as meaning making takes account of the provisionality of contexts. At a first glance, learning is defined by the school without reference to contexts, which we, however, consider to be essential for a full understanding of the affordances of mobile devices for learning. Since the beginning of the nineteenth century, the school has been a distinct institution, more or less segregated from the outside world. Formal learning in school is shaped by a standardised context comprising teachers, students and a curriculum, which hides the contextual character of learning. But there have always been attempts to make the walls of the school permeable and to widen the context for learning. This happens, for example, by opening the school to the neighbourhood, by inviting grandparents to history lessons, by visiting the fire station in elementary school, by growing vegetables in a school garden, etc. The German dual system of vocational training sends students to work as apprentices in companies with a contract and payment but teaches them also as students in specialized, publically funded schools. The permeability of the school to the world of facts and everyday life is organized by linking 'real' life situations to teacher-guided instruction. These curricular practices have a theoretical basis in 'situated learning' as discussed by Lave and Wenger (1991). One essential feature of *situated learning* is the construction of knowledge as meaning making in situations and activities in authentic contexts.

Internet access in school, usually mediated by a personal computer, opens up contexts for learning. Normally, scholastic practices around technology-enhanced learning (TEL) place traditional media functions such as the representation of knowledge in the foreground and not the function of context generation. Scardamelia and Bereiter's proposal (1999, 2005) to consider the 'school as a knowledge building organization' opens the pathway to modern and digital user-generated contexts. In their line of argument, knowledge building includes the building of *knowledge contexts*. Technological developments put mobile devices more and more in the role of interfaces for digital contexts and spatial situations around activities. We walk around with our mobiles in our hands and access the Internet, communicate with peers, take pictures, post them on Facebook, etc. The mobile interface supports the individualised construction of provisional contexts. The question is how they support learning framed by a curricular definition within clearly delineated learning contents and competences. The examples below are a first exploration of the capacity of mobile devices to generate contexts for learning. The curricular settings of these examples were developed within the traditional rationale of schools to open their doors to the outside world such as the excursion to the fire station in elementary school. That means, the situations of learning within the school were linked to situations with learning options such as a botanical garden or a bicycle workshop offered outside of school. The first didactic endeavour was to integrate mobile devices into the situation inside and outside of the school. Situated learning offers guidance how to do it; it remains really challenging, however, to widen curricular situations to learner-generated contexts.

Context-awareness is a well-established notion in the TEL literature. In the following, we will briefly discuss some of this literature – without any claim of comprehensive coverage; instead, our intention is simply to show how our understanding of the term is rather different to that prevailing in the existing literature in that we do not so much focus on context-aware 'computing', i.e. 'computational systems that can sense and respond to aspects of the settings in which they are used' (Dourish 2004, p. 1) but – as can be seen from earlier sections – on the generation of contexts for meaning making in and of the world with and through key affordances of mobile devices and related services, in particular multi-functionality and convergence.

Yang et al. (2008), for example, define context-aware and ubiquitous learning as 'a computer supported learning paradigm for identifying learners' surrounding context and social situation to provide integrated, interoperable, pervasive, and seamless learning experiences' and they see it characterised by the following eight technical features: mobility, location awareness, interoperability, seamlessness, situation awareness, social awareness, adaptability and pervasiveness (p. 1). In addition to the technical orientation of their thinking – seamlessness, for example, is conceptualised as 'the provision of everlasting service sessions under any connection with any device' rather than, for example, in terms of linkage between and across learning episodes in terms of continuity and progression – the focus on situation awareness, which is central to our understanding of mobile learning, rather lacks reference to the social processes through which knowledge is constructed.

Benamar et al. (2013) consider the main focus of context-awareness to be on the embedding of 'learning activities' into everyday life or work through mobile devices and services (p. 58). For them, the focus is on the 'design and engineering of pervasive learning systems' (p. 58). Inherent in this thinking is the timely provision or 'delivery' of material relevant for specific tasks in specific situations, i.e. a transmission-based approach.

Ogata and Yano's work (2004) on context-aware support for language learning aims to provide learners with appropriate polite expressions and could, arguably, be considered to be more socio-cultural in orientation as it focuses explicitly on social interaction and how it can be supported through ubiquitous technology. The list of characteristics cited by Ogata and Yano are also far less technical in orientation: permanency, accessibility, immediacy, interactivity and situating of instructional activities (p. 27). Nevertheless, for them, too, appropriacy of information transfer remains at the center of attention rather than, for example, sociolinguistic and pragmatic considerations.

One strand of the literature on context-awareness focuses on the challenges associated with information management and discusses technological tools to support the identification of relevant content, for example, through data mining and social network analysis as well as the design and 'delivery' of learning activities, for example, in the form of recommender systems (see Wild et al. 2009), adaptation engines (Economides 2008), learning systems (Yang 2006), or authoring and run-time tools (Zervas et al. 2011). Again, transmission rather than construction of knowledge or contextual information gathering mechanisms appear to be in the foreground here.

Other contributions to the field focus on the conceptual architecture as well as the development of context-based ontologies (Hong and Cho 2008) or frameworks (Fisher 2012), i.e. they take a very technological perspective often around Schilit et al.'s (1994) definition of context as information characterising the situation of people, places and/or physical or computational objects.

Nevertheless, we *are* influenced by a leading proponent of the TEL literature, namely Dourish, as already mentioned above, who considers context not as a representational problem but, instead, as an interactional one (p. 4). This is a view we share. Dourish considers it to be important how and why people 'achieve and maintain mutual understanding of the context for their actions' in the course of their interactions (p. 5). We, too, consider mutual understanding important and see it as evidence of learning having taken place.

In addition to context-awareness, the notion of 'augmented reality' has started to feature in the specialist TEL literature. It, too, is linked to context-aware learning and warrants a brief discussion here. One particularly noteworthy contribution comes from Specht and colleagues (Specht et al. 2011), which discusses the application of mobile augmented reality for learning and identifies various dimensions of user context. Augmented reality, as understood by Specht et al. (2011, p. 117), is 'a system that enhances a person's primary senses (vision, aural and tactile) with virtual or naturally invisible information made visible by digital means' with the system requiring 'to perceptually embed the information into the enhanced (re)presentation of the world view'. They go on to describe how educational objectives, such as illustration, exploration, understanding, reflection, collaboration and performance, can be connected to the usage of certain dimensions of context, such as independent context, identity, location, environment, relation and time, through digital augmentation. We consider augmentation of variables of the learning environment through dynamic 3D objects, sensor-based layers, augmented books, real-world object scanners, collaborative tags and annotations and instructional augmented reality and real-world object manipulation to have great potential, and we see it as a possible bridge of our educational perspective, which is informed by psychology, philosophy, sociology and media studies, and the much more technological perspectives advanced in the TEL literature.

One popular use of augmented reality in classrooms is through QR codes, which enable mobile phone users to interact with digital content, for example, by linking computer visualizations onto real-life objects by scanning in (teacher-generated) codes on their mobile phones.[1]

[1] For examples, see http://www.freetech4teachers.com/2013/02/5-uses-of-augmented-reality-in-education.html, http://nikpeachey.blogspot.ca/2012/04/getting-learning-out-of-classroom-with.html, http://moblearn.blogspot.co.uk/2013/01/ar-in-mobile-learning.html, http://ignatiawebs.blogspot.co.uk/2012/10/augmented-reality-ar-overview-and.html or http://www.freetech4teachers.com/2012/02/interesting-ways-to-use-qr-codes.html.

Towards a Pedagogical Perspective on Mobile Learning: Some Examples

The by now well-accepted curricular model of situated learning, on which our work draws (see Pachler et al. 2010a), defines learning as a 'situated activity' (Lave and Wenger 1991, p. 29), which means that learning is 'configured through the process of becoming a full participant in a sociocultural practice' (p. 29). Increasing participation is another essential feature of the model of situated learning beside the feature of learning as meaning making in situations introduced earlier. In explaining this in the foreword to Lave and Wenger's book, William F. Hanks stresses the dependence of learning as a 'process that takes place in a participating framework' (p. 15), which he categorises as a 'learning context'. As a main feature of this *framework* Hanks as well Lave and Wenger identify, among other features, (modes of) participation, the different perspectives of participants and 'prefabricated codes and structures' (Hanks 1991, p. 16.). Hanks summarises the substantial dependence of learning on context by emphasising the implementation of learning situations within the structures of contexts: 'The activity of understanding … comes down to recognising and implementing instances of structure, filling them in with an overlay of situational particulars, and relating them to a "context" (which is in turn structured)' (p. 17).

Learning and understanding 'arise out of … mental operations' in contexts and lead to 'mental representations of individuals' (Hanks 1991, p. 17). In Hanks' definition one can see the term *context* used in line with our understanding of it, which we delineated above as a frame under construction, which combines actions and representational resources. By comparison with cultural and social situations of the time – Hanks wrote his foreword in the late 1980s/early 1990s – the concept of situational learning could not envisage today's individualised and ubiquitous digital mobility with a variety of mobile devices as cultural resources in the hands of learners. Therefore, the actual question is: how can or should formal institutions of learning, with their established practices of teaching, engage with mobile phones/smartphones/tablets as everyday life features? Following the logic of situated learning, we propose among other things context-aware learning. For other aspects of our response to this question, see Pachler et al. 2010a, b.

The following examples try to illustrate context-aware learning and teaching with reference to situated learning. They stem from participating observation with two observers and validation by the responsible facilitator. The research methodology underpinning the examples is probably best described as a version of 'community-based participatory research' with workshops characterised by active stakeholder participation in the process with the goal of influencing change in the target group.

The first example depicts the possibility of achieving a high level of reflexivity in learning in a botanical garden and shows how to open up a formal science lecture to the context of TV entertainment. During as well as supplementing a formal presentation by a science teacher in a biological garden, young migrants deal with the specialised and unknown vocabulary required by adopting the format of a TV show. For their presentation, the students use the video application of their mobile phones. This group of students newly arrived in Germany, but with differing legal status, e.g. as asylum seekers, unaccompanied children without identification papers or as members of a family with full legal status of an EU citizen but without German language competence. We use the term migrants (as opposed to immigrants) deliberately in this chapter with reference to a definition provided by the UNESCO as 'any person who lives temporarily or permanently in a country where he or she was not born, and has acquired some significant social ties to this country' (http://www.unesco.org/most/migration/glossary_migrants.htm). The term 'immigrant' tends to have more political connotations and refers to persons with the legal right to reside permanently in a particular jurisdiction and to work without restriction.

The second example turns the college into the object of a photo investigation by students with their mobile phones/smartphones as the starter task of a new course. Beginning with an activity around basic spatial awareness, the students were invited to add to their photos of the college site their preferred images from outside of college. The presentation of the photos depicts the contexts inside and outside the college. Here context awareness is an issue for both students and teachers. The third example proposes a design, which combines periods of situated learning with mobile devices with periods of teacher-guided instruction.

A Biology and Chemistry Workshop in the Botanical Garden

As already mentioned, it is a well-known practice of situated learning to open the school doors and visit sites such as a botanical garden or a museum with their specific forms of learning. In the botanical garden, a science specialist organized a workshop with the aim of getting the students acquainted with the specificities of such an environment. The students were aged between 14 and 16 and investigated the structure of the botanical garden among other things with the geo-positioning function of their smartphones. They looked for the relationship of running and stagnant water and plants, etc. They also analyzed water looking for pollution with acid or other kinds of contamination. The group comprised newly arrived young migrants, who could cope with the German language quite well orally in everyday life, but not with the special language of a scientist. The main purpose of going outside the school was to become aware of different and new forms of teaching and learning and to experience other practices and communities of learning. This is an essential feature of situated learning (see Lave and Wenger 1991 and Wenger 1998). For learners with a migration background, it is arguably very important to problematise experiences with learning in their new cultural context in order to become aware of their specificity in relation to potential explicit and implicit differences in German contexts of learning.

A botanical garden is not primarily an explicit site of and context for learning. The students mostly enjoyed their visit of the site, followed the scientist around, took a lot of pictures and videos with their mobile phones and produced a kind of diary of their visit. This diary gave some sustainability to their investigation of the botanical garden in that it supported an awareness of the garden as a learning context at a simple level. This matched the character of a botanical garden as an area for wellness, beauty and leisure time. From everyday life, the students knew how to use their mobile devices to produce a photo dairy, although the photo diary ran under the heading of a portfolio. Back in the school and together with their teacher, the students worked on the diary and produced a report for which they used PowerPoint slides. In the school PowerPoint is well accepted and it can work well as an interface for written language and images. This teacher-guided and language-centred processing of the experiences in the botanical garden led to a higher level of awareness of the learning site *botanical garden*. The quality of the German language used on the PowerPoint slides is not perfect and not free from spelling mistakes but the slides are a successful record of reflection, which combines photos with written language. The slides formed the basis of a public presentation in school. During the process of creating the slides, the students reconsidered their excursion by selecting relevant photos and by verbalising and reflecting on their experience of learning.

The final and formal lecture by the scientist at the end of the three half days of the excursion represented a big disruption in the process of the investigation. The scientist presented his lecture in the lecture theatre of the botanical garden. It was like a traditional university presentation of a science experiment. The students were polite and pretended to understand what the scientist presented and explained but the presentation in German was too complex for them to follow and featured a highly specialised vocabulary. In view of that, the workshop facilitator suggested a video role-play: an imagined host of a TV talk show presents words with an emotional connotation. The group of students asked the scientist to repeat important parts of his lectures and they recorded essentials from this lecture. Afterwards they checked their short videos for emotionally important words. For example, they appreciated words with relevance to cooking even if they were unknown and complex. In her PowerPoint summary one girl wrote: ‘But I learned difficult words e.g. gentle words, unfriendly words, beautiful words, silly words’ (Fig. 3.1). The photo on the slide depicts the rehearsal for the imagined TV talk show. One girl recorded the talk show presentation of another girl. The students worked intensively and in a highly concentrated manner on the selection of the vocabulary for the talk

Fig. 3.1 Photo diary of the excursion to the botanical garden. During this excursion on three half days, the group of newly arrived migrant learners took photos and videos in the botanical garden as a site for learning, which opened and supplemented the learning context of the school

Fig. 3.2 Migrant students contextualise unknown and specialised science vocabulary by rehearsing for a pretend TV talk show. In the lecture theatre of the botanical garden, they use the video application of their mobile phone for the role game as a TV presenter

show, they listened several times to the recording from the lecture, took written notes and rehearsed the presentation of the selected vocabulary several time. Because of the video recording, the students worked collaboratively in order to achieve a good result.

In categories of awareness, the students jumped out of the verbal stream, which they did not understand, and worked on individual items of vocabulary. They worked not by memorising but by practising within the well-known context of entertainment TV. They were successful because they changed the context by acting in front of or behind the mobile phone's video camera. Their experience of media practices of entertainment TV supported their appropriation of an extremely specialised vocabulary by contextualising it as a TV genre (Fig. 3.2). The role play in the form of a TV talk show brought a media-related practice into the lecture theatre, which supported the students to act as real learners, which transformed them from a polite but excluded and passive audience into active participants in an open context. In the categories of s*ituated learning,* the TV context opened the role of an *apprenticeship* in the 'community of practice' of the German language. In the terminology of the theory of *situated learning* (Lave and Wenger 1991, p. 29) it is 'legitimated peripheral participation':

> It concerns the process by which newcomers become part of a community of practice. A person's intention to learn is engaged and the meaning of learning is configured through the process of becoming a full participant in a sociocultural practice. This social process includes, indeed it subsumes, the learning of knowledgeable skills. (Lave and Wenger 1991, p. 29)

A Scenario for Learners in Media Design

The workshop discussed in this section was aimed at a group of learners about to rejoin formal education in a college for young people aged between 16 and 20. The course focused on media design. The intention was to give participants the opportunity to gain a new and positive understanding of learning in the context of formal education. The *key to success* for such a new and positive understanding was considered to be to harness learning in school with the experiences of informal learning of participants in everyday life. The mechanism to achieve this was the mobile phone, which we consider to be a normalised cultural resource of everyday life of young people. By means of the mobile phone, participants can bring elements of their informal learning into formal education contexts.

The initial 2-day course began with an investigation of the college through the students' personal mobile phone. Students worked in groups. After the investigation, the teacher gave an introduction to the presentation software Prezi in the computer lab of the college. The students subsequently worked on a Prezi presentation of their photo investigation of the college. At the end of the second day, the student groups were asked to present their results to the class. The teacher invited them to bring in other material from outside of the school, e.g. from the Internet or from at home. Whilst working on the Prezi presentation, the students selected one image, a photo taken during the investigation of the school or brought in from outside of the school. This image was printed on a t-shirt. The obvious reason for the t-shirt was to show the student's personal identity by means of the selected image within the social unit of the new class. The social unit in turn was represented by there being a t-shirt for everybody. A second, didactic reason was to make visible the context in which the students stood in relation to the new college environment. Thirdly, the intention was for specific resources in the students' contexts to become visible, especially for the teacher (Fig. 3.3).

Fig. 3.3 The class with their t-shirts, which represent communality and individuality

Fig. 3.4 Images of the school in the style of artistic still lifes: a calm garden environment with bench and tree; details of the floor from the art studio; mannequins from the fashion department; toilet sign

At face value, the different images signal individuality; a second viewing, however, shows a variety of contexts, resources in contexts and accesses to contexts. The resources presented and the routes of access to the selected contexts are relevant because they are part of individual students' self-presentation as part of their learning habitus.

The t-shirt images shown in Fig. 3.4 originate from the investigation of the college. They are a result of the students' perspective of the college. The photos appear as still lifes, which convey an important message for these students, namely, to see the college from the perspective of a young artist. The images are not about teaching, learning or assessment but convey interests around media design. Furthermore, these four images give the impression of the students as people with a professional-orientation, not as beginners but as experts. The bearer of the t-shirt invites themselves to be addressed professionally not as unmotivated young person or as an outsider.

The other implicit contexts in evidence, not depicted here, also carry messages about context relationships, which are of high relevance to the teacher; mainly as media experts we are interested in media design. The students do not need extrinsic motivation, but professional equipment with reference to Internet design, to social media within a professional context of fine arts and design. They expect, of course at a low level of awareness, a context for design and communication with media practitioners and it is important for students not to be patronised. Their t-shirts problematised the following themes:

- Entertainment media: One t-shirt displays the faces of the two protagonists of a manga cartoon for young people, *L vs. Kira*. The girl who chose this image portrays herself as a media specialist. In so doing, she refers to the media design focus of her course but with clear reference to media and design styles outside of school.
- Internet and social media: One student presents himself as a dancer on a photo which he had downloaded from his Facebook site. A girl wears the well-designed characters MEHR on her t-shirt, another a stylish and also well-designed combination of faces and characters. One boy chose a photo of a fashion model. Perfection in the use of the Internet and a world of design are the messages here.

- At home, family and peers: One t-shirt features photos with friends having a good time; the style is that of a photo album. The girl who wore this image on her t-shirt was probably looking for a familiar context with peers within the college context.
- National origin: One young man featured his national colour on his t-shirt; perhaps it carried the meaning of being politically aware as a migrant.

The Results from a German Field Study Around Episodic Planning

The first applied research project for mobile learning in Germany was realised by *Medien + Bildung.com*, a public institution which supports schools in the field of media education in one of the German federal states. The aim was to introduce mobile phones into standard forms of teacher-guided instruction from elementary school to advanced level. In 2009 and 2010, eight instructional units were taught over a time span of around 6 weeks, the normal duration for units of work in German schools. Each teacher was accompanied by a professional media educator from *Medien + Bildung.com*, who supported planning and evaluation, brought in a supportive infrastructure and cooperated with the teacher during the realisation of the instructional units. The practical phase in schools was started by a meeting with parents. The project schools invited students to use their personally owned mobile phones, only some of which were smartphones. *Medien + Bildung.com* also provided 20 Internet-capable mobile phones. Fuller accounts of the project are available in German: Friedrich et al. 2011 and Bachmair et al. 2011.

The basic didactic idea was grounded in the model of a *street for guided learning* and *market squares for situated learning* with mobile phones. Like in the two examples earlier, episodes of situated learning were combined with episodes, during which the teacher presented information or actively *channelled* the learning process of the students. In the examples of the botanical garden or the exploration of the college, this *channelled* learning took the form of a science lecture with students as passive audience in a lecture theatre or the applied training on the use of a new piece of software under the guidance of the teacher. The metaphor of a *street* for learning comprises guidance by a teacher along established curricular specifications. The *market squares* were organized as episodes of situated learning, in which the students constructed their knowledge on their own but within a given, but open structure (Fig. 3.5).

For example, beginners in reading and writing were asked to use the mobile phones of their parents on an expedition (*Foto-Safari*) for capturing so-called Elephant Words, compound nouns such as ‘Müllverbrennungsanlage’ (incinerating plant) or ‘Osterhase’ (Easter bunny), which they found on the weekend in their neighbourhood.

The pupils brought these words into the school on their parents’ phones and printed out the photos at school. This was organized by the teacher. The expedition for the *Elephant Words* is an episode of situated learning to which the teacher adds a phase of instruction, e.g. a group discussion of the printed photos. Afterwards, and in an episode of pair work, the pupils interviewed each other using the audio application of the phones. The primary curricular aim of this episode of situated, mobile-

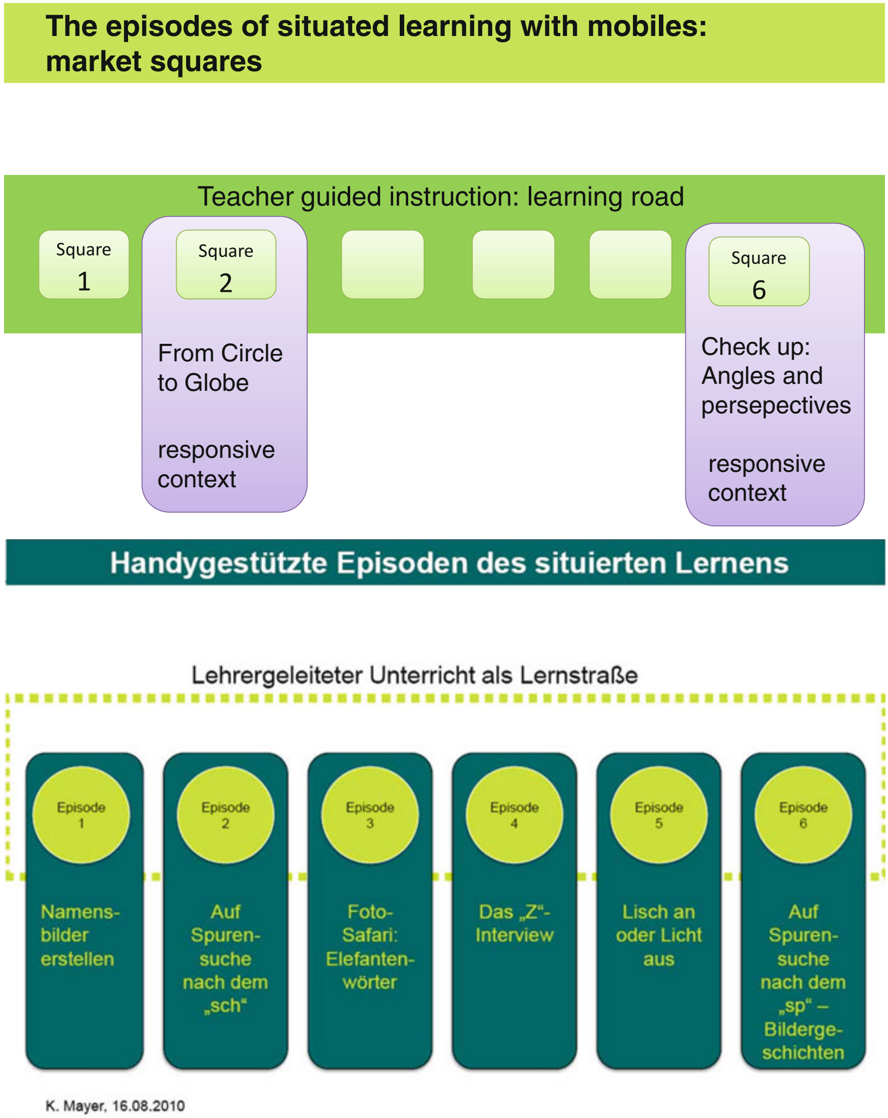

Fig. 3.5 Episodes of situated learning with mobile devices (*yellow* and *green squares*) on the *street of learning*, through which the teacher guides beginners in reading and writing in the elementary school (see Bachmair et al. 2011, p. 17) (Color figure online)

supported learning was to practice the correct reading and pronunciation of the *Elephant Words*. The second, subsidiary aim was to bring in the family languages of pupils, which ranged from the regional German dialect to variants of Russian or Turkish. Because the *Elephant Words* stemmed from the pupils' everyday life worlds, different family languages became normal in the German school context.

Discussion and Conclusion

In episodic didactic design, mobile phones linked the context of the school with its typical feature of teacher-guided instruction to the context of everyday life worlds of learners and attendant informal learning. Usually the practices of speaking, reading and writing inside and outside of school are clearly divided, nonetheless with sanctions from school, e.g. not to disturb the classroom conversation by chatting about the Easter bunny. Mobile applications such as the photo or the audio recording create a common practice of speaking and writing. In the categories of Hanks (1991, p. 17), learning and understanding are 'mental operations' and 'representations of individuals' in the context of the school, curricular emphasis, e.g. on precise spelling, is amalgamated with the context of everyday life and the fun of discovering *Elephant Words*. The interrelation of the two contexts is mediated by mobile devices and brings together the different options and resources inside and outside of school. With their specific learning options, students and teachers generate a common context as a frame under construction, which combines actions and representational resources. The combining tool is the mobile device.

In the example of the botanical garden, the mobile device opens up the conversation options of the TV talk show to the specialised science lecture. By accompanying the students through the botanical garden, the mobile device helps to objectify visible features of the garden and further the breadth of the students' learning experiences. By means of the objectifying potential of photos and videos, the students achieve a higher level of reflexivity about the context of their learning than would be possible through typical learning options and learning resources. This is possible because of the support of the teacher within more or less traditional curricular methods like writing a summary report for a PowerPoint presentation.

The t-shirt and Prezi project followed a similar rationale. The representation of one image out of the normal context inside and outside the school is the stimulus for a new awareness of the students about the school as a context, which is linked to their competences and expertise in their everyday lives. The teacher gets the chance to identify the context of students, which frames their school learning.

As a result of our discussion, we conclude that mobile devices can be helpful as context comprehension resources and that *mobile* comprehension can succeed if the interrelationship of different modes of teaching and learning matches the affordances of learners and the teaching practices of the school as well the affordance of the mobile devices.

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Chapter 4
Employing a Framework to Examine the "Niche" for Mobile-Assisted Seamless Learning from an Ecological Perspective

Yanjie Song and Siu Cheung Kong

Abstract Despite the fast development of digital technologies and the booming of seamless learning pedagogical practices, mobile-assisted seamless learning generally happens only in specific and defined learning episodes leveraged by a uniform type of mobile devices. How school students use their own devices to support their seamless learning and what affordances of the mobile devices students would like to use for supporting their seamless learning have rarely been discussed and explored. This chapter, from an ecological perspective, discusses how seamless learning happens using the concepts of affordance network (functionally bound possibilities in an environment), effectivity sets (the attunement and employment of affordance network), and "niches" (sets of affordances or experiences), and develops a framework to examine the "niche" for seamless learning. Implications of the framework are explored. A seamless inquiry into understanding "anatomy of fish" is cited as an example to elaborate the framework.

Introduction

In the year 2006, Chan et al. envisage:

> Over the next 10 years, … We see that ready-to-hand access creates the potential for a new phase in the evolution of technology-enhanced learning (TEL), characterized by 'seamless learning spaces' and marked by continuity of the learning experience across different scenarios (or environments), and emerging from the availability of one device or more per student ("one-to-one") (p. 5).

Today, at the beginning of 2013, such educational practices are advancing toward this trend. Studies on seamless learning are booming (Wong and Looi 2011). The majority

Y. Song (✉) • S.C. Kong
Department of Mathematics and Information Technology,
The Hong Kong Institute of Education, Hong Kong SAR, China
e-mail: ysong@ied.edu.hk

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of these studies have focused on "mobile-assisted seamless learning," which refers to seamless learning mediated by 1:1 setting (Wong 2012; Wong and Looi 2011). In general, these mobile-assisted seamless learning studies have provided students with a uniform type of devices that serve as a standalone application with or without connection to a central desktop application (Chan et al. 2006; Pinkwart et al. 2003), for seamless personalized learning (Song et al. 2012), seamless inquiry-based learning (Toh et al. 2013), seamless language learning (Wong et al. 2012), exploring affordances of seamless mobile learning for enhancing students' lived experiences (So et al. 2008), and so on.

In the digital age, mobile technologies have become embedded and ubiquitous in students' lives, with increasing multimedia resources, supporting rich information exchange and social interactions, adding features, and converging technology applications (apps) into a mobile, wireless handheld environment. More and more students bring their own mobile devices wherever they go for their own needs like learning, personal management, communication, and fun across different platforms "just-in-time" and "just-in-place." These devices include iPhone, smartphone, iPad, Google Nexus, Tablet PC, and the like which generally run different operating systems such as iOS, Android, or Microsoft OS, and across different platforms. Nevertheless the learning platforms are more and more compatible with each other, which is conducive to mobile-assisted seamless learning.

Mobile-assisted seamless learning is categorized into ten dimensions by Wong and Looi (2011). Although one dimension concerns "combined use of multiple device types" (p. 2367), how school students use these devices to support their seamless learning and what affordances of the mobile devices students would like to use to support their seamless learning have rarely been discussed and explored. This chapter, from an ecological perspective, aims to develop a framework to examine the "niche" for seamless learning in order to understand how learning can be best supported with sets of affordances. A "Bringing Your Own Device (BYOD) for seamless science inquiry project" in a class of a primary school is cited as an example to elaborate the framework.

Literature

Seamless Learning from an Ecological Perspective – Distributed Cognition

Mobile technology educational applications have been predominantly curriculum-based, and learning is supported in intentionally designed environments rather than in everyday practice (Song 2011). However, learning does not happen only in specific and defined learning episodes. Seamless learning concerns the whole environment of seamless integration of learning experiences across formal and informal learning contexts, across individual and social learning, and across physical world and cyberspace (Wong and Looi 2011). What learners really do in the technology-rich environments and how they coordinate their learning activities in the environment requires a theory tailored to understanding the interactions between learners and various resources in the environments. These resources include social resources such as people, and material resources such as information resources and technological resources (Palfreyman 2006). "Distributed cognition" deals with such issues (Hollan et al. 2000; Hutchins 1995). The theory, sharing ecological and social cultural perspectives, holds that learning takes place in context and recognizes the importance of the relationship between the learner and the resources in the environment in knowledge construction (Hollan et al. 2000; Hutchins 1995). The theory focuses on three kinds of distribution at least: (a) knowing may be distributed across the members of a social group; (b) knowing may involve coordination between internal (capability) and external (resources in the environmental) relations; and (c) knowing may be distributed through time in such a way that the products of earlier events can transform the nature of later events (Hollan et al. 2000, p. 176). This approach, different from the "fixed-eye vision" (Reed 1988, p. 282), takes the interaction of the learner and environment as the unit of analysis. According to Reed (1988), perceiving what we need, perceiving the values of things involves selecting and detecting the information specific to these things. What needs and intentions in the seamless learning environment learners perceive and what values of the mobile devices can be used to achieve the needs and intentions require an understanding of the relationship between the learner and resources in the environment, which involves the concept of affordances.

Affordances and Affordance Networks

According to Gibson (1977), affordances refer to "what it [the environment] offers the animal, what it provides or furnishes, either for good or ill" (p. 127), exist only "within the context of an animal–environment system" (Gibson 1979, p. 2), and are possibilities for action dynamically emerging in the environment (Normak et al. 2012). No matter whether an observer can perceive the affordances or not, they are there to be perceived. However, the same environment perceived by different observers may have different affordances. The environment is embedded with unlimited possibilities for action or affordances which make our life possible. The possibilities in the environment are bound functionally. These functionally bound possibilities extended in time that can be acted upon to realize particular goals are referred to as affordance networks (Barab and Roth 2006).

Effectivities and Effectivity Sets

Effectivities are complementary to affordances (Gibson 1979). Barab and Roth (2006) posit that "If an affordance is a possibility for action by an individual, an effectivity is the dynamic actualization of an affordance" (p. 6). Effectivities are related to the capabilities of the observers to act on the affordances of the resources in the environment

(Young et al. 2000). For example, a stool that affords sit-on-ability for an adult may not offer the same affordance for a small child. Only when the observer picks up information specific to the relevant properties of those things can one's intentions be realized (Reed 1988), and the affordances are seized and transformed into effectivities (Shaw and Turvey 1981). The attunements and behaviors that an individual can employ to realize the affordance network (functionally bound possibilities) are referred to as an effectivity set (Barab and Roth 2006).

Niches

The elements of affordance network and effectivity set are highly related to the creation of "niche" by an individual in an environment. The environment in which, from the perspective of an individual, "has optimal living conditions for performing actions related to their life" can be considered the "niche" of the individual (Normak et al. 2012, p. 264). This is different from the material world surrounding the person from the material aspects of one's mind (Barab and Roth 2006). Comparing an animal's "habitat" with its "niche", Gibson (1979, p. 128) assumes that a "habitat" is where it lives, whereas, its "niche" is how it lives, and suggests that "a niche is a set of affordances" for a particular individual; while, Barab and Roth (2006) further interpret the "niche" as a set of experiences. The contents of any "niche" are dependent on the individual's available affordance networks and effectivity sets in the environment (Barab and Roth 2006). The term "niche" has recently been used in the context of ecological learning systems (Normak et al. 2012; Song 2013; Pata 2009).

Framework of the "Niche" for Seamless Learning

As is mentioned in the previous section, one's "niche" is inseparable from affordance networks and effectivity sets, so is the "niche" for seamless learning. In the seamless learning environment, there exist various social resources such as teachers and peers, and material resources such as learning tasks, learning resources, mobile device tools, computer technologies and facilities, and so on. These learning resources provide many possibilities for the learners to take advantage of. These possibilities are connected with each other and will be expanded in the learning process to achieve certain learning goals. The expanded possibilities contribute to seamless learning affordance networks. Once learners perceive the affordance network, and make attunements to act on the network, then the affordance network will be realized and be transformed into an effectivity set. Thus, the "niche" for seamless learning is the results of interactions among the three inter-connected elements: the seamless learning environment, the affordance set, and the effectivity set (see Area A in Fig. 4.1). The "niche" for seamless learning cannot be achieved if an element is stripped off from these.

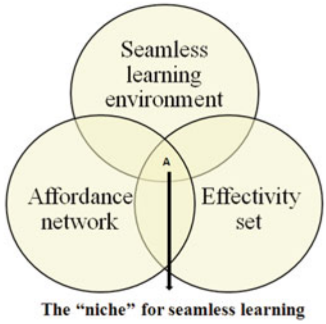

Fig. 4.1 Framework for examining the "niche" for seamless learning

Application of the Framework

In this section, we would like to show how the framework is applied to a research on science inquiry. We choose a topic on "the anatomy of fish" in a science learning unit of "Biodiversity" as an example to elaborate how to examine "the niche" for seamless inquiry.

Background of the Study

The science inquiry into understanding "the anatomy of fish" situates in a 1-year ongoing case study of the "Background of the Study on Bring Your Own Device (BYOD) for seamless science inquiry" in a class of Grade Six with 28 students in a primary school in Hong Kong. In the BYOD project, the students were encouraged to bring their own devices for science inquiry. Twenty-one students brought their own devices to school, ranging from iPad, iPhone, Smartphone, to mobile phones. Seven students did not have their own mobile devices, but the school lent iPad to these students so that they could benefit from the seamless inquiry. In addition, Edmodo – a free social network platform – was used for students to communicate, share information and work, submit assignments, and coordinate learning activities seamlessly. Evernote was used for students to record their learning journeys, make reflections, and share with peers. Skitch – a mobile app – was also recommended to the students for annotating images. Students were divided randomly into seven groups, each with four students. We choose one group's inquiry as an example to elaborate the "niche" for seamless learning framework. The group has four members with two boys and two girls under the pseudonyms of Ran (boy), Tin (boy), Ling (girl), and Nini (girl). Tin and Nini used their own iPad, Ling used her own smartphone, and Ran used iPad borrowed from the school.

Pedagogical Design of This Study

In the pedagogical design, an inquiry-based learning model was developed based on previous research (Hakkarainen 2003; Krajcik et al. 2000) to guide students' inquiry into "the anatomy of fish." The model consists of six elements, namely, (a) "engage" in topics and problems of inquiry, (b) "explore" the information to address the problems, (c) "observe" the phenomena in the experiment, (d) "explain" the analyses and outcomes of inquiry, (e) "reflect" the processes and outcomes of inquiry, and (f) "share" the findings and reflections. The model was integrated into three learning activities carried out in a seamless learning environment across class, home, school lab, and online learning spaces (see Table 4.1). In the course of students' inquiry-based learning, the inquiry-based learning model was used as a scaffolding to guide the

Table 4.1 Science inquiry into understanding "the anatomy of fish" in a seamless learning environment

Seamless learning environment		Description
Learning activities and related inquiry skills	Activity 1 (out of school)	Engage: Access Hong Kong marine fish database online http://www.hk-fish.net/chi/database/feature/feature.htm
		Explore a few kinds of fish in the wet market, take photos, find out the names of the fish, and upload them to Edmodo. Students also share other information about fish on Edmodo
	Activity 2 (in school lab)	Observe (in school lab)
	Observe & explain	There are four kinds of fish prepared by the teacher for each group to observe. They need to observe and find out the scientific names of the fish and their anatomy. They are encouraged to make full use of their mobile devices in the observational process
		Explain (In school lab)
		Label the body parts of the fish using the mobile app Skitch to explain the anatomy of a fish and upload it to Evernote which is shared in Edmodo
	Activity 3 (online)	Reflect and share : Reflect on the following guided questions in Evernote and share in Edmodo:
	Reflect & share	Q1: Why are the four kinds of fish called fish?
		Q2: What have you learned?
Material resources: Mobile device tools	Embedded functions	Students can use the mobile devices to take photos, videos, or record audio files for their own learning needs
	Evernote	A suite of free software and services designed for note-taking and archiving (refer to http://en.wikipedia.org/wiki/Evernote for details)
	Skitch	A free app that helps one communicate visually with friends by annotating images, then save or share the annotation (refer to https://play.google.com/store/apps/details?id=com.evernote.skitch for details)
Social resources	Teachers	Teachers facilitated students' inquiry skills; recommend and encourage the students to perceive and use various affordances of mobile apps in their inquiry such as Evernote and Skitch, and the social network platform Edmodo; and identify the affordance networks for the inquiry
	Peers	Peers communicate, coordinate, discuss, share, and evaluate their products via Edmodo platform, and face-to-face (F2F) interactions by making use of the affordances networks

students' inquiry; in the meantime, the students were encouraged to perceive and act on the affordances of various tools and resources in the learning environment to obtain optimal conditions for learning, where the "niche" for seamless learning was identified.

The rest of this section elaborates how students perceived the affordances in the seamless learning environment, joined the affordance networks, and attuned their behaviors to actualize the affordance network through the three inquiry activities.

We first report the activities the students involved in the science inquiry followed by analysis of the "niche" for the group's seamless inquiry using the framework.

Examining the "Niche" for Inquiry into the "Anatomy of Fish" in Seamless Learning Activities

Activity 1: Engage and Explore (Out of Class)

In the first activity, to be engaged in the topic of inquiry and explore information to address inquiry problems of understanding the anatomy of fish, first the group members Ling and Tin used the mobile device as an information access tool to explore various websites about fish, and chose the information that they considered helpful for their inquiry, then used Edmodo as a sharing tool to share the chosen information so that the information could be distributed across the group members (see Figs. 4.2 and 4.3) using their mobile devices or computers at home. Secondly,

Fig. 4.2 Website about fish shared by Ling

Fig. 4.3 Website about fish shared by Tin

Fig. 4.4 Photo taken in a wet market shared by Ling

the group members Ling and Tin also went to the wet market and made use of the capturing (picture-taking) tool of their mobile devices to take a few pictures of different kinds of fish and shared them on Edmodo to help the group get a general understanding of fish. Figure 4.4 posted by Ling is an example of it. Thirdly, Ling also made use of the capturing (recording) tool of the mobile device to describe the kinds of fish the consumers bought observed by her in the wet market and upload the recording to Evernote – a note-taking tool which was shared on Edmodo.

In this activity, the learning goals were to explore information about "fish." The group members Ling and Tin had the capability to perceive the affordances of information access, capturing, sharing, and note-taking tools of the mobile devices. In addition, the teacher played a facilitating role of designing the learning activity to make the students stay focused on the learning goals. In addition, the teacher's recommendation of the Edmodo social platform and the Evernote app also increased the capability of the students to perceive and act on the affordance network to achieve their learning goals. This affordance network was employed by the group members to realize effectivity set and achieve their "niche" for seamless fish information exploring and sharing purposes. This "niche" or "set of experiences" for learning in this activity was obtained, and distributed to the next activity [see Fig. 4.9a Niche 1].

Activity 2 Observe and Explain (in School Lab)

In the lab, the four group members observed four kinds of fish prepared by the teacher, and each of them was responsible for finding out the scientific name of one kind of fish by joining and expanding the affordance network formed in activity 1. All group members were able to use an iPad or a smartphone as an information access tool to access the information about fish online on Edmodo (see Fig. 4.5),

Fig. 4.5 Mobile devices used by the group members

and use the mobile app Skitch as an annotating tool to label the body parts. Figure 4.6 shows that Ran was comparing the information recommended by his group member Tin on Edmodo about the fish online to the fish he was studying while labeling the anatomy of the fish using the mobile app Skitch.

In this activity, the group’s learning goals were to observe and explain “the anatomy of fish” via an experiment. It was observed that the group members were more skillful in using the mobile device as an information access tool to obtain useful information about fish posted on Edmodo early while trying to identify the kind of fish on hand in the experiment. In the meantime, the students’ affordance network established in activity 1 was expanded to include the annotation tool of Skitch recommended by the teacher to achieve their goals of presenting the names of the anatomy of fish. The expanded affordance network in the learning environment was employed by the group members to realize their effectivity set and achieve the goals of explaining “the anatomy of fish” in a visualized manner. This niche was further distributed to the next activity [see Fig. 4.9b Niche 2].

Activity 3 Reflect and Share

Succeeding the affordance network for learning from learning activity 2, the group members used Evernote as a note-taking tool to write their reflections and posted their labeled anatomy of fish to Evernote shown in Fig. 4.7a–d for sharing.

All the members wrote their reflections on Evernote except Nini. Tin reflected:

> Today, we did an inquiry into “fish”. The teacher divided the four kinds of fish among our group members 1, 2, 3 and 4. I’m group member 1. The fish I studied is shown in the

Fig. 4.6 Tin – working on the fish

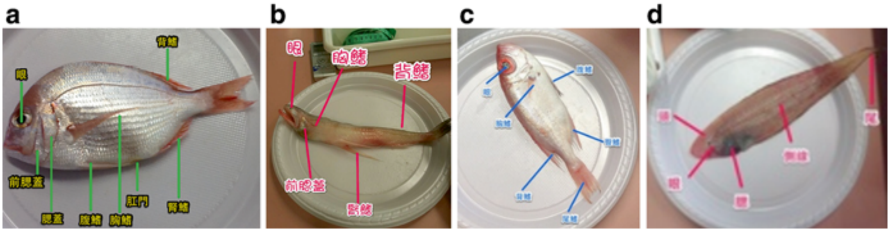

Fig. 4.7 Four kinds of fish labeled by Tin, Ling, Ran, and Nini (**a**) Fish by Tin, (**b**) Fish by Ling, (**c**) Fish by Ran, (**d**) Fish by Nini

> above picture (see Fig. 4.7a). I divided the fish into several parts. They are: eye, pelvic fin, gill, spiny dorsal fin, pelvic fin, anal fin, etc. The fish I studied and the other fish my group members studied all belong to fish because all of them have gills, anal fins, fins and scales. Based on these, I know that they are fish. In addition, before the experiment, I thought that fish is hard if it is not cooked; after the experiment, I learned that what I thought was wrong. Fish meat is not hard at all, but soft and elastic. From the experiment, I learned a lot of knowledge about fish, for example: anatomy, features, quality of fish meat and scales. (Translated from Chinese)

Ran reflected that "I learned in Wednesday's experiment, different body parts of the fish, for example: lateral line, gill, pelvic fin, and spiny dorsal fin. The fish I studied is 'Golden Threadfin Bream'." Ling reflected that "All of them are fish because they use gills to breathe and use fins to move." But Nini did not make reflections. Facilitated by the teacher, "Great! Well done!! Can you find the name of this fish?" Nini found out the name and detailed information about the fish and posted it on Edmodo (see Fig. 4.8).

Fig. 4.8 Teacher’s feedback and Nini’s response

In this activity, the group’s learning goals were to make reflections on “why the four kinds of fish are called fish” and what they learned after the experiment to deepen their learning about fish. The members made use of their sets of experiences gained from previous events/activities to reflect on what they learned using Evernote app as a note-taking tool. From their reflections, we note that all group members achieved their “niche” for the inquiry into the “anatomy of fish.” The reflection shows that their learning was resulted from the perceived and used affordance network consisting of different tools on the mobile devices as well as the social resources such as peers’ work and teacher’s encouragement. As such, their learning was distributed across the group members, was relevant to their capability in perceiving and acting on the affordance network in the seamless learning environment, and was distributed chronologically through successive learning activities in such a way that the products (such as searched and shared resources) of earlier activities help transform learning later activities (such as the labeled fish anatomy, and deepened understanding of fish). In this process, their “niche” for inquiry into the “anatomy of fish” was achieved [see Fig. 4.9c Niche 3]. It is no denying that the inquiry-based learning model and the designed learning activities also provided affordances in the seamless learning environment to guide the students’ inquiry, hence contributing to their science learning.

The group’s evolving inquiry learning process across the three activities was presented graphically in Fig. 4.9a–c.

It is also noted that although the group members work toward the same learning goals, due to different members’ capability of perceiving and acting on the affordances in the environment, their employed affordance networks were different. In Activity 1, Tin and Ling were more able to perceive and act on the affordances provided in the learning environment to realize their “niches” for information exploration; in Activity 2, Tin did the best in making use of the affordance network such as online resources about fish gained in the previous activity, and using Skitch to label the fish

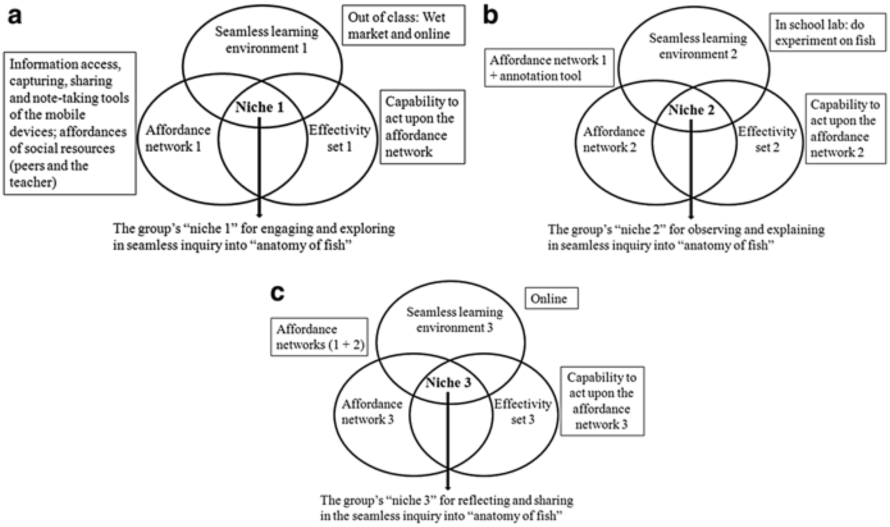

Fig. 4.9 (**a**, **b** and **c**) A series of niches for learning actualized in different activities

to archive his learning "niche" for understanding anatomy of fish, and Nini seemed to be the weakest; and in activity 3, Tin also made the best reflections among all members in the group based on the previous sets of experiences ("niches") and extended affordance networks. In the learning process, Tin could perceive more affordances of both social and material resources in the environment. These affordances extended and were seized by Tin to realize his "niche" for the seamless inquiry. Learning occurred because Tin identified the affordance networks that bore similar structures and even created new affordance networks in the successive and connected activities. In the whole learning process, the teacher's facilitation, recommendation of the apps, and learning activity design played an important role in increasing the students' capabilities to perceive and act on the affordances in the seamless learning environment. The other group members also achieved their "niches" for seamless inquiry into the anatomy of fish but with narrower perceived affordance networks than Tin's. This indicates that it is important to foster students' capabilities of perceiving and expanding the affordance networks to realize the "niches" for seamless learning.

Implications of the Framework

The concept of affordance network used in a seamless learning environment has four implications:

1. Affordances of various resources (material and social) in a seamless learning environment do not stand alone, but are functionally connected together to form affordance networks and are employed by learners to achieve certain goals.

For example, the affordance network of the inquiry-based learning environment leveraged by mobile technologies concerns not only the affordances of the mobile devices but also the affordances of the inquiry-based pedagogy, learning strategies, learning activities, teacher's facilitation, and peer interaction.

2. A learner's capabilities of perceiving and acting on the affordances of various resources in a seamless learning environment can be increased along with the employment of and attunements to functionally bound possibilities or affordance networks. McGrenere and Ho (2000), working in the context of software design, develop a two-dimensional framework in order to enhance the design that maximizes two dimensions (the degree of perceptual information and the degree of affordance) that are important for the perception and use of the affordances by a user as shown in Fig. 4.10. According to the framework, perceiving and acting on the affordances depends on two factors: the degree of perceptual information and the degree of affordance (McGrenere and Ho 2000). Increasing the two factors in the design will help increase the capability of the user to perceive and act on the affordances offered by the designed software. The same is true in perceiving and acting on the affordances in the seamless learning environment. For example, regarding the mobile technology affordances, nowadays more and more features and applications are built into the mobile device design to increase the affordances and perceptual information of the mobile device to the users so that their capability of perceiving and seizing the affordances can be increased. For example, SMS was originally developed for communication purposes between mobile holders. Later it was used for commercial purposes to make advertisements, and more recently has been increasingly used for educational purposes because more and more affordances have been perceived by learners and educators for enhancing language learning (Cavus and Ibrahim 2009; Song 2008), increasing awareness for collaborative activities (Liu et al. 2008), and so on. In another instance, mobile apps (applications) that are not designed especially for education are likely to tip into mainstream educational use that spans all of education across the world due to their low cost, ease of use, and fast delivery (Johnson et al. 2012).

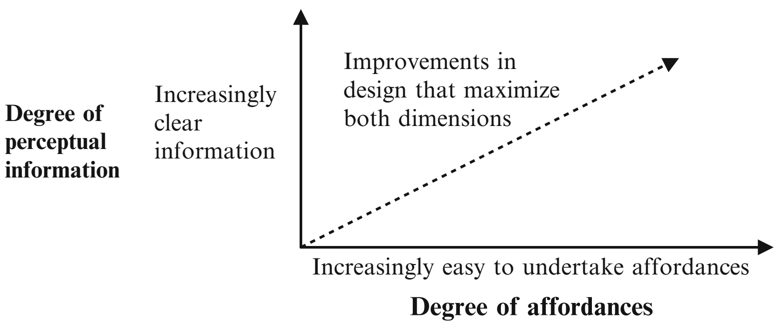

Fig. 4.10 Representing the affordance and the information that specifies the affordance (McGrenere and Ho 2000, p. 7)

In our example of a group's inquiry into the "anatomy of fish," the group members' capability was increased when they were increasingly involved in the inquiry-based learning activities because learning was distributed across time that the affordance network established in the earlier events was employed to transform the nature of later inquiry events (Hollan et al. 2000). In addition, the teacher's facilitation and peers' information sharing and exchange were also crucial for increasing capabilities of perceiving and acting on the affordances for "just-in-time" and "just-in-place" learning as learning was distributed across individual and social spaces. All in all, the affordances of both social and material resources in the seamless learning environment contributed to the affordance network for learners to perceive and act upon to achieve specific inquiry-based learning goals.

3. A learner's "niches" can evolve and transform learning across time. Due to different abilities and needs, the affordances in the seamless learning environment to be perceived and act on varied from learner to learner, hence result in different affordance networks, which in turn, result in different effectivity sets once they are employed to achieve certain learning goals. Therefore, the "niches" for seamless learning will also vary from learner to learner because of different affordance networks and effectivity sets. Just as Chemero (2003) posits, different individuals, with different abilities, may have "nonoverlapping niches" (p. 191) or sets of experiences. This implies that "the environment from an ecological viewpoint … is a complex set of relations among various affordances" (Shaw et al. 1982, p. 196). However, these "niches" for seamless learning do not stand alone. Seamless learning involves not just succeeding in one situation, but developing the capacity and interest to create new action possibilities, even reconstructing relations that might not have been readily apparent in the dynamic structure (Shaffer 2004, cited in Barab and Roth 2006). In addition, learning in this view is an ecological and social phenomenon that is distributed across time, individual and social, and internal and external spaces, which enables the learner to engage in progressively more adaptive individual–environment relations. As a learners' "niche" expands, it involves sets of experiences with increased effectivity sets and extended multiple affordance networks which evolve into new ways of individual–environment interactions (Barab and Roth 2006). Learning happens or transfer occurs when the learner becomes aware that different contexts, even with different contextual resources, have similar underlying affordances networks (Barab and Roth 2006).
4. This framework focuses on the interacting concepts of affordance networks, effectivity sets, and seamless learning environments grounded in ecological psychology and distributed theories. Using this framework to examine the "niche" for seamless learning suggests that learners should be provided optimal opportunities for exploring the affordances of the mobile devices and social resources in across different learning spaces. BYOD provides a technology model conducive to learners' explorations in an ecological learning environment supported by mobile technologies. However, we admit that the technology model BYOD alone could not be the full explanation for helping learners learn (Kobus et al. 2013). Rather, it is its combination with appropriate pedagogies that contributes to the learning process.

Conclusion
The chapter, from an ecological perspective, discusses how seamless learning happens using the concepts of affordance network (functionally bound possibilities in an environment), effectivity sets (the attunement and employment of affordance network), and "niches" (sets of experiences), and develops a framework of the "niche" for seamless learning. A seamless inquiry into understanding "anatomy of fish" supported by BYOD is cited as an example to elaborate the framework. Implications of the framework are explored. Employing the framework of the "niche" for seamless learning helps us understand how learners interact with the seamless learning environment and recognize that joining in the affordance network, expanding and even creating the affordance network is the key to realize effectivity sets and hence obtaining the "niche" for seamless learning.

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Chapter 5
Self-regulation: A Critical Learner Characteristic for Seamless Learning

Li Sha

Abstract This chapter illustrates an inherent link between mobile seamless learning (MSL), an innovative model of learning, and self-regulated learning (SRL), an active area in contemporary educational psychology. This link is rooted at defining characteristics of MSL: learner-centric, and demanding on seamless swift across learning contexts/scenarios. These characteristics expect that learners as agents of their own learning are motivated to and to be able to learn anywhere and anytime. Based on this link, an analytic SRL model of mobile learning was proposed as a conceptual framework for understanding mobile learning, in which the notion of self-regulation as agency is at the core along with the recognition of mobile devices as social, cognitive, and metacognitive tools, and importance of teachers' and parental autonomy supports. This model elicits that the advanced mobile technologies and devices just provide the technological and physical infrastructure of and the possibility for mobile seamless learning, and learners' SRL knowledge and skills is essential for learners to realize this possibility by engaging themselves in MSL behaviorally, motivationally, and metacognitively.

Introduction

Mobile technologies forge seamless learning spaces, and the continuity of the learning experiences across different scenarios or contexts (Chan et al. 2006; Wong and Looi 2011; Looi et al. 2010; Frohberg et al. 2009). In the past decade, research in mobile seamless learning (MSL) proceeded along two lines. One line as a mainstream in this field is focused on effectiveness and design of mobile seamless learning systems (Wu et al. 2012). The other line is on characterizing seamless learning and revealing challenges facing MSL from a variety of theoretical perspectives (Sharples et al. 2005, 2007; Wong and Looi 2011; Sha et al. 2012a, b; Terras and Ramsay 2012). For example, Sharples et al.'s (2005, 2007) efforts have initiated an uncompleted course toward theorization of seamless learning. Wong and Looi's (2011)

L. Sha (✉)
Learning Research and Development Center (LRDC), University of Pittsburgh, Pittsburgh, PA, USA
e-mail: lishahn@yahoo.com

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comprehensive review of the literature recognizes ten dimensions that characterize the notion of MSL, which can be further grouped into three higher-level categories reflecting its key elements: *technology focus*, *pedagogy focus*, and *learner focus*. Placing emphasis on learners rather than technology or pedagogy, Terras and Ramsay's study (2012) identified significant challenges facing effective mobile learning from the psychological perspective.

Along the second line of research in MSL, this chapter illustrates how its nature can be understood from the perspective of self-regulated learning (SRL), an active area in contemporary educational psychology, and proposes an SRL analytic model of MSL as a conceptual framework for designing and analyzing learner-centric seamless learning systems in K-12 education. This model is intended to provide insights from a psychological perspective into designing and analyzing effective MSL systems that are supposed to be learner-centric/learner-dominated other than simply equipped with mobile devices.

Existing Efforts to Characterize Mobile Seamless Learning

In attempts to theorize mobile seamless learning, Sharples et al (2005, 2007) recognize that a theory of mobile learning should first grasp its unique characteristics that qualitatively differentiate from other types of learning including e-learning (e.g., using desktop or laptop computer), and then should embrace the contemporary accounts for the considerable factors underlying successful lifelong learning. This implies that there is a need to uncover central features first, and then to apply appropriate theories of learning to analyze and design MSL environments that should conduce to lifelong learning.

There are two influential definitions initiating attempts to characterize mobile seamless learning in the literature. O'Malley et al. (2003) define mobile learning as any kind of learning occurring when the learner is not at a fixed, predetermined location, or when the learner takes advantage of the learning opportunities offered by mobile technologies. In Chan et al.'s seminal study (2006), seamless learning refers to situations where individuals can learn whenever they want to learn in a variety of scenarios and where they can switch from one scenario to another easily and quickly whenever they want to do so, by means of personal mobile devices. It can be recognized that these definitions highlight an essential characteristic of seamless learning, that is, its core element lies in human beings (learners) rather than mobile/ubiquitous technologies. Following this logic, Wong and Looi (2011) identified learner focus as one of the aforementioned three major elements of MSL, referring to a learning style and habit of mind. This learner-centric standpoint on seamless learning (Wong 2012) logically entails explorations of what the basic aspects presumably are of the learning style and habit of mind. In other words, what are the main learner characteristics needed for effective mobile technology-supported seamless learning?

In light of the view that psychology as a study of human thinking and behavior is assumed to offer conceptual and methodological frameworks under which learner-centric seamless learning can be analyzed and developed, Terras and Ramsay's work (2012) identifies five central psychological challenges facing effective mobile learning. The first challenge is due to the context-dependent nature of memory. Mobile seamless learning suggests frequent and quick switch, and inconsistency between the contexts/scenarios in which encoding of information (e.g., science museums) and the contexts/scenarios in which decoding of information (e.g., classroom tests) takes place. This inconsistency between learning contexts/scenario may negatively influence seamless learning achievement (Bruning et al. 2004). The second challenge has to do with a tenet of cognitive psychology that human cognitive resources (i.e., capacity of working memory) are limited (Bruning et al. 2004). In seamless learning, swifts between different learning scenarios requires more cognitive resources a learner to manage extraneous cognitive load resulting from some scenarios that are not designed primarily for them or not familiar to them. The third challenge is due to the contemporary view of cognition that cognition is distributed and situated (Robbins and Aydede 2009). Seamless learning is not only individual, but also social, encompassing personalized and social learning – a dimension of MSL (Wong and Looi 2011). The fourth challenge is that learners need to possess some metacognitive knowledge and skills in order for them to be able to learn the right thing at the right time at the right place in mobile seamless learning (Peng et al. 2009). The fifth challenge is that individuals differ in their attitudes toward the use of mobile technologies, which influences the degree to which they engage in seamless learning. Essentially this is an issue of motivation.

Taken together, the first three challenges are due to some limitations of human being's cognitive functioning as cognitive demands increase imposed by learning while mobile. The fourth and fifth challenges are concerned with general individual differences in metacognition and motivation that effective seamless learning entails. The implication of these two categories of psychological challenges for research and practices in mobile seamless learning are salient in the two domains of psychology recognized in the psychological sciences (Winne and Nesbit 2010). One domain is "heuristics that describe generic relations between instructional design and learning"– called as the psychology of "the way things are" (Winne and Nesbit 2010, p. 653). It is in principle likely out of learners' control (e.g., context dependency, cognitive resource limitation, distributed cognition in seamless learning), but can be shaped by external influences such as instructional design. The other is the domain of psychology of "the way learners make things," shedding light on the learner side. The ways that learners make things differ from one another in terms of whether individuals are willing to make (i.e., individual differences in motivation) and able to make (i.e., individual differences in cognitive and metacognitive abilities). Establishing a comprehensive connection of mobile seamless learning with both of the domains is beyond this chapter whose focus is on how the psychology of "the way learners make things" provides insight into characterization and design of MSL from the perspective of SRL (to be introduced in detail later).

Self-regulation as Agency: An Intrinsic Demand for Mobile Seamless Learning

As noted already, a theoretical underpinning of MSL should embrace the contemporary accounts for the considerable factors underlying successful lifelong learning (Sharples et al. 2005, 2007). Lifelong learning has been a popular phrase used to characterize what people need in the twenty-first century. It is characterized as "(1) the learning is often self-directed and driven by interest and needs; (2) formal learning activities and environments are often less prominent compared with informal ones; (3) it takes place in tool-rich environments; and (4) it is often carried out as a collaborative activity." (Fischer and Konomi 2007, p. 339). These imply that lifelong learning in nature is self-directed and intrinsically motivated, as well as social and collaborative across learning settings (formal settings vs. informal settings). Can SRL theories guide design of MSL to foster lifelong learning?

Ubiquity, the most significant characteristic of wireless and mobile technologies, makes it possible that learners can learn the right thing at the right time at the right place (Peng et al. 2009). It "refers not to the idea of 'anytime, anywhere' but to 'widespread', 'just-in-time', and 'when-needed' computing power for learners" (Peng et al., p. 175). One of the fundamental challenges for the twenty-first-century learners is not only what they learn, but also how and when they learn in the ways that make meaningful learning happen. This inevitably results in some key questions in studying seamless learning in the context of K-12 education. For example, who takes the responsibility to determine what, when, where, and how to learn, i.e., to undertake seamless swifts across learning contexts/scenarios? Are students willing to and able to make a right judgment about what the right things are, when the right time is, and where the right place is in terms of meaningful learning?

Taken together, a relevant question asked by Vogel et al. (2009) is: do using mobile technologies really lead to effective seamless learning? They likened it to the old adage that leading a horse to water does not mean making it will then drink from the water. Learner-centric seamless learning logically supposes that students are the agents (masters) of their own learning in some manner. In this sense, effective MSL systems should provide a means by which students can exercise agency to control their own behavior and cognition. Subsequently, what does agency mean in the field of psychological sciences?

In social cognitive theory, the notion of agency refers to an emergent capability of individual humans to make choices (i.e., setting goals) and to act on these choices constituted primarily through interaction between brain activities and sociocultural contexts (Bandura 2001; Martin 2004). Agency is both determined by and determining the environment and is philosophically connected to Piagetian constructivism, Vygotskiansocioculturalism, and determinism (Martin). Agency has four main features: *intentionality*, *forethought*, *self-reactiveness*, and *self-reflectiveness* (Bandura 2001).

Intentionality represents the power to originate actions for a given purpose. "To be an agent is to intentionally make things happen by one's actions" (Bandura 2001, p. 2).

This implies that although mobile devices make it possible for students to access mobile seamless learning a MSL system, they may still not engage in seamless learning if they have no intention to do so (without purpose). *Forethought* suggests that human behavior is motivated and directed by anticipated goals and outcomes, as well as planning (Bandura 2001). An agent is supposed to be able to take appropriate actions, and to self-regulate motivation, affect, and action through goal setting. In this sense, effective seamless learning should not be random, but rather conscious and goal-directed. *Self-reactiveness* suggests that an agent "has to be not only a planner and forethinker, but a motivator and self-regulator as well" (Bandura 2001, p. 8). Agents are assumed to have not only the deliberative ability to make choices and action plans but also the ability to act on appropriate courses of action. *Self-reflectiveness* represents agents' metacognitive ability to subjectively judge their online state of learning against the goals as standards they intentionally set with shaping from external feedback from peers or teachers.

The first two features of human agency are essentially associated with the role of motivation in human behavior; the last two attach the importance to people's metacognitive knowledge and skills. These converge on two key components of self-regulated learning: *motivation* and *metacognition,* which will be introduced in detail below.

Self-Regulated Learning

Definitions and Main Components of Self-Regulated Learning

In light of contemporary view, human behavior is conceived of as the product of an internal guidance system that inherently is organized; thus, the mechanism underlying human behavior is a system of self-regulation (Carver and Scheier 1998). Self-regulation can be defined as "self-generated thoughts, feeling, and actions for attaining academic goals" (Zimmerman and Schunk 2004, p. 323) and is not viewed as a general trait or a particular level of cognitive development but rather as highly context-specific (Schunk 2001).

The construct of self-regulated learning (SRL) is subsumed under a general concept of self-regulation (SR) (Boekaerts and Corno 2005). Thus, in educational practices teachers should not expect students to engage effectively in self-regulation equally under all circumstances. Conversely, some circumstances may be presumably better suited for nurturing students' effective engagement in self-regulated learning than others. This suggests that educational researchers should work closely with teachers to use any possible approaches to designing learning environments that make productive SRL possible.

In Bandura's social cognitive theory (i.e., Reciprocal Determinism) (Bandura 1986; Zimmerman and Schunk 2001), personal cognition (e.g., cognition, affect) is reciprocally determined by behavioral (e.g., opening a webpage) and environmental (e.g., teacher's feedback, parental support) factors. Humans are viewed as proactive, self-organizing, self-regulating rather than reactive organisms solely either shaped by external environmental influences or reflexively stimulated by genetic inner impulses (Bandura 2001; Martin 2004). In this theory, people as agencies are both products and producers of the environment in which their cognitive and behavioral functioning is determined. This implies that the effectiveness of effective MSL environment on learners' behavioral engagement in learning is mediated by learner characteristics (personal factors) such as prior knowledge, goals, and self-perception of the task. Thus, designing a MSL environment is not only concerned with technological issues, but with learners' personal factors and behavioral patterns.

In social cognitive theory (Zimmerman and Schunk 2001), self-regulated learners should be able to: (a) personally improve their ability to learn through selective use of metacognitive and motivational strategies; (b) proactively select, organize, and even create advantageous learning environments; and (c) play a significant role in choosing the form and amount of instruction they need. These assumptions about the nature of SRL essentially converge at a fundamental meta-theoretical element intrinsic in all SRL models – the construct of agency. Self-regulating learners are agents who are self-proactive and self-organizing (Bandura 2001; Martin 2004).

In sum, self-regulating learners actively participate in their learning processes metacognitively as well as motivationally and behaviorally (Zimmerman and Schunk 2001). This definition embraces the two key elements of human agency: *motivation* and *metacognition*.

Motivation

From a cognitive perspective, "Motivation is the process whereby goal-directed activity is instigated and sustained." (Schunk et al. 2008, p. 4). First, motivation refers to a mental process rather than a state or product. Thus, it cannot be observed directly but rather must be inferred from its products – behaviors such as choice of task, effort, and so on. In this sense, motivation is internal and inferential in nature. Second, motivation is inherently related to goals that provide impetus for action. Thus, goal setting is indicative of motivation. In this sense, effective seamless learning should not take place randomly and spontaneously; instead, learners are supposed to consciously set learning goals at the beginning of a learning process and monitor and adjust their goals during the learning process according to emergent internal and external feedback (e.g., from peers and teachers) from their ubiquitous learning. Third, motivation can be expressed as either physical or mental activities. Physical activities involve effort, persistence, engagement, and so on. Mental activities entail cognitive operations such as encoding, retrieving, planning, monitoring, solving problems, and so on. The former is observable and the latter is unobservable and inferential. This actually elicits a methodological issue about how to measure learners' unobservable motivation (e.g., interest) from observable, online data (e.g., log file data) that they generated in mobile seamless learning environments, which will be discussed in the next section. Finally, motivation leads to initiating and sustaining activities.

In self-determination theory (SDT) of motivation (Ryan and Deci 2000), autonomy is viewed as a basic innate psychological motive of human beings. The need for autonomy refers to a sense of control over one's behavior. Intrinsically motivated people engage in an activity because they find it innately interesting and enjoyable. In contrast, extrinsic motivation leads people to engage in an activity as a means to attain some separate outcome such as a reward or avoidance of punishment. Intrinsic motivation corresponds to the proactive, growth-oriented nature of human beings (Ryan and Deci 2000). Thus, the variance of student performance and achievement in MSL can be accounted for by the degree to which individual students are motivated intrinsically to ubiquitously engage in mobile learning activities.

Autonomy as an innate endorsement of one's action is one's subjective perception of or a sense of actions deriving from oneself – a feeling of choices over their own actions and thoughts. In classrooms, teachers cannot directly give students an experience of autonomy, but rather provide autonomy supports – a set of interpersonal behaviors to foster students' intrinsic motivation (Reeve et al. 2008). Since mobile technologies make it possible to bridge students' learning activities in both formal (e.g., in schools) and informal settings (e.g., in homes), autonomy supports that nurture intrinsic motivation should be extended from classrooms to individual students' homes.

In developmental and educational psychology, external autonomy support is viewed as the extent to which parents value and use techniques that facilitate independent problem solving, choice, and self-determination in their children (Soenens et al. 2007). There are two major sources of autonomy support underlying students' intrinsic motivation and self-regulation of learning when they are involved in a mobile learning environment: classroom teachers and parents.

Metacognition

Metacognition refers to what people know about their cognitive and memory processes, and how they put the metacognitive knowledge to use in regulating their information processing and behavior (Koriat 2007). This indicates that metacognition is composed of two facets: *knowledge about cognition* and *regulation of cognition* (Schraw and Dennison 1994). The former refers to the knowledge about one's cognitive processes (e.g., I understand my intellectual strengths and weaknesses); the latter refers to the capabilities of planning, monitoring, and controlling our cognitive processes (e.g., I organize my time to best accomplish my goals) (Veenman et al. 2006). Metacognition has been referred to as cognition of cognition, knowledge about one's cognitive process, as well as skills of regulation of cognition (Nelson 1999).

Regulation of cognition is composed of: *metacognitive monitoring* and *metacognitive control* (Winne 2001). Metacognitive monitoring about learning refers to learners' subjective judgments of their degree or nature of *learning* before, during, and after study. The output of monitoring is our judgment about the products and processes that are monitored. For example, when a student monitors how well he or she has mastered an assigned task, the output of this monitoring could be his/her recognition that either he or she has learned it well or not well, i.e., *Judgments of learning* (JOLs) (Koriat 2007). Metacognitive control is deciding how to act based on the products of metacognitive monitoring, and this control (e.g., study item selection, study time allocation) determines the progress of learning (Winne 2001).

SRL as a Framework for Technology-Enhanced Learning

The inherent link between seamless learning and self-regulated learning can be illustrated from a broader perspective. Azevedo (2005) examined how self-regulated learning as a guiding theoretical framework conceptualizes and assesses learning with advanced computer technologies, presumably including mobile technologies. In general, less is known about the mechanisms underlying students' learning with hypermedia environments than the technological use in learning (e.g., designing MSL systems). Thus, more research is needed to use multiple theoretical lens and multiple methods for data analysis for better understanding the complex nature of learning with technology-advanced learning environments.

Winters et al. (2008) did a critical analysis on a wide variety of empirical studies of SRL within TEL environments covering a range of educational levels (from middle school to postgraduate programs), and subject areas including science, math, and art. Two main research problems are recognized. The first problem is about the roles of learner characteristics and task characteristics in student achievement of SRL in TEL environments.

Learner characteristics primarily involve learners' prior knowledge, metacognitive strategies (e.g., setting goals, planning), and motivation (e.g., self-efficacy, goal orientation) in the literature on this issue. By and large, many studies found these learner characteristics are positively correlated with the gains in conceptual understanding. For example, Greene and Azevedo (2007) found that middle school students who were actively engaged in cognitive and metacognitive processes, such as coordinating various sources of information, making inference, and making subjective judgment of learning, had larger knowledge gains from pretest to posttest than those who were less active in cognitive and metacognitive processes.

Task characteristics refers to a set of pedagogical conditions (limits) teachers set under which students' learning takes place such as classroom goal structure, learner control, etc. For example, McManus (2000, as cited in Winters et al.) found that linear hypermedia environments with few choices were not helpful for high SRL students, whereas nonlinear environments with some choices were a hindrance to low SRL students. Giving students some choices is necessary for fostering their SRL (Reeve et al. 2008).

The second issue involves learning supports needed to enhance students' SRL. Research revealed that TEL environments that function as both cognitive tools (e.g., creation, communication, note-taking) and metacognitive tools (e.g., self-monitoring, self-evaluation) are conducive to nurturing SRL. For example, Kramarski and Gutman (2006) found that students who were equipped with metacognitive self-questioning in a mathematical e-learning environment outperformed those without that metacognitive tool during problem solving. They also concluded that effective metacognitive supports within e-learning environments need to be distributed, integrated, and multiplied in that students have more opportunities to take advantage of the environmental affordances in self-regulating their learning.

In the recent explorations, Dabbagh and Kitsantas (2012) proposed a pedagogical framework regarding how social media (e.g., blogs, wikis) can be used to support SRL in personal learning environments (PLEs) like MLS systems. There are three levels of interactivity in it. At level 1, students using social media are encouraged to self-regulate their learning by the approaches such as goal setting and planning, which is characterized as personal information management. Level 2 is concerned with social interaction and collaboration when students engage in social media. The role of regulatory processes (i.e., self-, co-, and socially shared regulation) in computer-supported collaborative learning (CSCL) was comprehensively examined in Järvelä and Hadwin's recent study (2013). At level 3, students are encouraged to synthesize and aggregate information generated from the previous levels. This actually corresponds to metacognitive monitoring and control in SRL.

Understanding Mobile Seamless Learning Under the Lens of Self-Regulated Learning

Again, do using mobile technologies really lead to effective seamless learning (Vogel et al. 2009)? This section illustrates how SRL theoretically and methodologically sheds some light on this challenge.

Understanding Mobile Seamless Learning from the Theoretical Perspective of SRL

The ubiquity and mobility of mobile technologies make seamless learning possible and offer the students a larger degree of freedom to exercise agency as self-regulation of their own learning by means of these choices than the conventional classroom-based, teacher-centered curriculum. For example, imagine that when a student sat on school bus going home, she recalled mentally what the teacher instructed in today's lesson and suddenly realized she could not exactly remember the definition of a concept learned in the class. Actually, she was metacognitively monitoring her cognitive process, yielding a judgment of learning (JOL) – "I could not remember the definition of the concept I just learned from today's science lesson." Based on this JOL, she would decide to access to the smartphone on the bus to see if she could find the definition from the online materials or access the Internet to find it. This is her metacognitive control operation. Again, this exemplifies the handheld computer can be not only used as cognitive tool (Chen et al. 2008), but also metacognitive tool. One may argue that any e-learning system can be designed as metacognitive tools. Without this mobile learning system, she would have to do the same thing when she was at home; thus, this metacognitive control operation (finding the definition) would be delayed or even very likely ignored due to some emerging distractions. Thus, the above analyses also manifest the inherent relationship between mobile learning and SRL. The ubiquity of MSL makes SRL on the fly possible. The students that are equipped with a mobile device are able to metacognitively monitor and metacognitively control in each and every phase of SRL anytime and anywhere.

What that student did on the bus (an informal setting) actually is the continuing of the task the teacher assigned in the class (a formal setting). Thus, the learning activity occurring on the bus essentially breaks the boundary between formal learning and informal learning in a natural and logical manner. The bridge across the two settings of learning is built not only by means of the MSL, but student's online metacognitive operations on her cognitive processes. She first metacognitively monitored the state of learning (i.e., self-assessing what she did not know yet about the content delivered in the class) and then metacognitively controlled her learning activity by accessing the smartphone to search the knowledge she bewared she was lacking.

In addition to metacognition, this self-regulated learning process actually involves another key component of SRL: motivation. Concisely speaking, thinking about a learning problem and accessing the Internet or MSL by using the smartphone outside the school displays that student's persistence of cognitive engagement in learning across various learning settings. Persistence is one of the indexes of motivation (Schunk et al. 2008). This example also manifests that the classification of formal settings and informal settings is artificial. For the students it is that natural to switch. Research has found that student motivation can account for whether and to what degree the students can actively engage in MSL processes metacognitively, motivationally, and behaviorally (Sha et al. 2012b).

Up to this point, a significant practical issue may emerge on the foreground of research in mobile learning, that is, how can researchers and teachers monitor and assess self-regulated learning processes occurring in such an informal learning setting as on the school bus, at home, or somewhere else out of the inspection of the teacher. This measurement problem originates from the central characteristics of mobile seamless learning, since learners can study whenever and wherever they can realize the need to engage in a learning process as how that student did on the bus. Essentially, this methodological issue to be addressed below is concerned how to measure SRL as event/process on the fly.

Measuring Mobile Seamless Learning from the SRL Methodological Perspective

Again, the central question regarding the measurement of SRL in MSL is how researchers and educators can accurately obtain the empirical data about SRL as on the fly event/process, namely, students' motivation, metacognition, and learning behaviors while they are involved in seamless learning across various settings. This is also an attempt to meet one of the challenges facing mobile learning. Vavoula and Sharples came up with (2009) – "measuring the processes and outcomes of mobile learning" (p. 54).

Researchers in educational psychology have increasingly realized the limitations of self-reports including post-study interview method as measures of SRL in real-time (Winne et al. 2002; Perry and Winne 2006). According to Perry and Winne (2006), first, self-report measures cannot unobtrusively capture the components of SRL on the fly. Second, according to learners' self-perceptions and evaluations of the features of their cognitive processes are shaped in the context in which learning occurs. To the extent the context proposed in a self-report instrument's protocol mismatches that in which learning actually happens, self-reported perceptions of learning can misrepresent learning. Therefore, when the students recalled how they engage in learning, they are actually off the context of real learning; therefore, the working memory of each individual at the time when they self-reported their cognitive actions is very likely to be occupied by a combination of a recall of how they did while studying and the enduring and stable cognitive and metacognitive strategies in the similar situations. In other words, to some degree they are not reporting what and how they actually did, but rather what they think they should have done according to their memory about what and how they tend to do under the similar circumstances (Sha et al. 2009). This is congruent with the important tenet in contemporary cognitive psychology (Bruning et al. 2004) about the nature of encoding and retrieval process, stating that memory is an inferential process involving reconstruction of information. That implies that "postdicting" learning processes by means of survey or interview is a reconstructive process in nature which is presumably guided by many enduring personal factors such as prior experiences, personal goals, perceived instructional objectives, etc., constituting the sources of so-called observe-expectancy effect.

Zimmerman (2008) comprehensively discussed the second wave of research in SRL, methodologically aimed at the development of online measures of SRL processes in authentic contexts. These innovative methods include computer traces, think-aloud protocols, structured diaries, direct observations, and micro-analytic measures. In accordance with this trend, measurement of SRL in MSL can adopt on-site classroom observations, field notes, audio and video recordings, interviews, student artifacts, self-documentation by participants, and log files on computers (see Looi et al. 2011; Zhang et al. 2010). Detailed description of the use of and the empirical findings by these methods in our project is beyond this chapter.

The general idea behind the trace-based methodology is that computer-based learning provides environments that enable researchers to trace learners' processes by means of log files that automatically and unobtrusively record accurate, time-stamped events of how learners choose and manipulate content while learning activities taking place (Winne et al. 2002; Perry and Winne 2006). Traces here refer to artifacts of observable students' actual cognitive actions automatically recorded in the log files while they engage in a task (e.g., using the networked smartphone to browse the study materials or upload animations to the MLE on the bus or at home).

In this regard, Boticki and So (2010) reported a software-based data gathering tool (called Quiet Capture) that enables researchers and teachers to unobtrusively collect the online data about what, when, and how individual students were engaged with using the MLE. In addition, capturing the time-stamped device screenshots provides sequential, qualitative, contextual, and pictorial information about the content, appearance, and formation of student artifacts that are created or edited in and out of classrooms. By classifying students' activities (cognitive operations) based on some criteria or coding scheme, this tool can provide the quantitative data about when and how long each individual works on each of those cognitive operations. Trace methods do not have to interrupt cognitive processing unlike a think-aloud, and do not rely on learners' fallible memories of how they studied unlike self-report surveys and post-study interviews.

Fusing fine-grained traces of actual student actions with self-reports will enable researchers to uncover the patterns of learners' actual online learning behaviors, the internal and external factors underlying the patterns, and the relationships between actual learning behaviors and learners' self-perceptions of seamless learning activities (Winne et al. 2002; Zimmerman 2008; Sha et al. 2012b). Eventually, this will enrich our knowledge that enables researchers and classroom teachers to design more effective mobile seamless learning that boost students motivated and sustain their engagement, thus meeting a key challenge faced in the learning sciences (Sawyer 2006).

An Analytic SRL Model of Mobile Seamless Learning

Among factors important for lifelong learning in the eyes of educational psychologists, motivation and self-regulation are two central determinants (Boekaerts 1997; Schober et al. 2007). Lifelong learning is by nature self-directed and driven by intrinsic motives (Fischer and Konomi 2007). Thus, lifelong learners are supposed to be self-regulating learners. A central augment in this chapter is that when learners are motivationally, metacognitively, and behaviorally engaged in the learning activities, i.e., self-regulate their own learning, they are not only yet led to "water" (seamless learning spaces) by means of mobile technologies and devices but also are able to proactively and strategically "drink" (acquiring and constructing knowledge) the right amount of water at the right time.

Putting the above together, an analytic SRL model of MSL was proposed (see Fig. 5.1) embracing a set of factors that are supposedly taken into account while designing and analyzing mobile learning. Specifically, under this model, at the center of the model is the notion of self-regulation as agency, referring to the learner characteristics that function as internal driving forces initiating and sustaining a self-regulated mobile learning process. The key learner characteristics include domain knowledge, prior experiences, motivation, and metacognitive awareness, epistemological beliefs, and so on. Second, mobile-assisted seamless learning as tool-mediated activities is supposed to take place in the platform of mobile technologies and devices, which presumably function as social, cognitive, and metacognitive

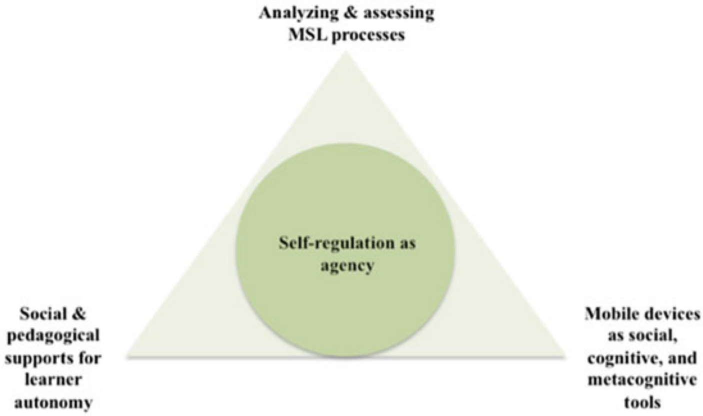

Fig. 5.1 An analytic SRL model of mobile learning

tools (Sha et al. 2012a, b). Past research in MSL largely focused on the first two functions and ignored the third one. Third, the development of mobile-assisted seamless learning system is presumably conducted around the tenets of SRL. Key in pedagogical design is offering learner some degree of freedom (i.e., autonomy supports from teachers and parents) in setting goals, monitoring and controlling learning processes (selecting tasks, strategies, and study time), assessing and evaluating learning activities. Sha et al. (2012b) exemplified how both classroom teachers' and parental autonomy supports account for the variance of students' learning behaviors in seamless learning processes.

Concisely, the key idea of this model is that the advanced mobile technologies and devices just provide the technological and physical infrastructure of and the possibility for mobile seamless learning, learners' SRL knowledge and skills is essential to realize this possibility by engaging in MSL behaviorally, motivationally, and metacognitively.

The mobility and ubiquity of mobile learning is in accordance with the contemporary view of cognition that cognition is in nature not only situated (Robbins and Aydede 2009), but dynamic and self-organized (Tschacher and Scheier 1999; Smith 2005). In a dynamic, self-organizing learning system, learners exercise agency in self-regulating cognition and behavior. Specifically, they initiate goals, monitor the state and progress of learning, control cognitive and motivational processes in a strategic way, and evaluate the attainments of cognitive engagement in learning tasks.

It is already shown that self-regulated learning, an active area in educational psychology, does provide a unique theoretical and methodological framework that can characterize well under mobile seamless learning. Specifically, first, the notion of agency – theoretical assumption of SRL – informs that effective MSL environments are expected to be designed to allow and offer learners some freedom of choice in learning processes such as self-perceiving assigned tasks (defining the task), setting their own goals and plan of learning, monitoring and controlling cognition and behavior, and so on. Social cognitive theory (Bandura 1986), the most influential theoretical underpinning of SRL, claiming that effectiveness of any learning environment on learners' behavioral engagement in learning is mediated by learner characteristics (personal factors) such as prior knowledge, goals, self-perception of the task. This is an initial attempt to contribute educational psychology (e.g., SRL) to instructional design of mobile learning. Second, SRL enables researchers and educators to theoretically understand and methodologically analyze the ubiquity of cognition and learning behaviors occurring in a mobile learning environment. Key is that both motivation and metacognition – two essential components of SRL are necessary to realize seamless learning by bridging learning across contexts and scenarios.

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Chapter 6
Reflections on Case Studies in Mobile Seamless Learning

David Metcalf, Max Jackson, and David Rogers

Abstract Seow and Looi have proposed a framework for describing seamless learning, and this article uses their framework to evaluate four case studies and identify outcomes and areas for future research. These cases of mobile seamless learning have been drawn from diverse contexts including children's STEM education, medical training, corporate orientation, and defense training. While each case is unique, there are underlying commonalities, including high levels of student engagement and satisfaction, and challenges to sustained deployment and replication by secondary instructional designers.

Based on our case studies, we identify *context* as a key attribute of seamless learning programs, meriting special consideration, specifically that the ability to fine-tune context in a seamless learning program may help educators balance instrumental and critical engagement.

Introduction

Conventional education takes place in a formal setting, in a specialized venue whose purpose is to create a space separate and apart from ordinary life where learning and knowledge can be inculcated optimally. The use of technology in formalized settings traditionally serves as a focal point for the class as a whole. Multimedia, presentation software, and smart boards are extensions of the lecture format. Against this backdrop of approved instruments, many forms of mobile, social, and simulation technology present opportunities for distraction and diversion, which can be a disruptive nuisance in a traditional classroom.

But they can also create novel learning experiences unlike any other. These experiences are *seamless*, where the learning occurs in a way that is *continuous* with everyday experience.

Seow et al. (2008) have proposed an innovative framework for understanding this aspect of learning. This framework identifies the following components which contribute to a seamless learning environment: *Space, Time, Context, Community, Cognitive Tools, and Cognitive Artifacts* (Looi et al. 2010).

D. Metcalf (✉) • M. Jackson • D. Rogers
University of Central Florida, Orlando, FL, USA

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Space is the area where the learning occurs – due to the mobile nature of seamless learning, this space can be anywhere and can itself serve as an object of observation and even interaction throughout the learning process.

Time plays a crucial role in the learning process, and seamless learning allows the pedagogical experience to take place both at times which are most convenient to the student and at times which can help solidify retention (i.e., through the spacing effect).

Context is the setting and activities in which the learning experience occurs. As an example, Seow et al.'s work discusses the difference context makes when students learn about plastic bags and waste while observing plastic bags in use at an actual supermarket.

Community in a seamless learning environment is made up of the fellow students, teachers, and domain experts. Interpersonal interaction generates unique questions and answers and ultimately solidifies the learning experience in a way that could not occur were students to study the material alone.

Cognitive Tools are tools which *extend* the thinking of the individual, facilitating their ability to access information and reflect upon their learning processes.

Artifacts are objects either spatially or digitally present which are generated by the students. These can be exchanged or referenced later, feeding into the concepts of *Community* and *Cognitive Tools* previously discussed.

This chapter will apply these principles to four case studies. These case studies demonstrate tools across multiple platforms, from a low-tech card game to a high-tech simulation program. The four case studies are *My Sports Pulse*, an STEM (Science Technology Engineering and Math) program for children delivered via text message; *Ride and Drive,* a tablet-based training aid for automobile sales staffs*;* *Combat Medic,* a training aid for military medical care providers; and *Virtual Family,* a training simulation for medical students. These case studies were selected from a range of programs developed by METIL (Mixed Emerging Technology Integration Lab) to illustrate diverse approaches to seamless learning experiences.

Though the seamless learning framework consists of several elements, our findings highlight the significance of context as being especially relevant to the creation of engaging seamless learning experiences.

My Sports Pulse

My Sports Pulse is an endeavor by the University of Central Florida to take the technological trend of smartphone technology and use it to inspire broader student engagement in STEM topics. In My Sports Pulse students use their mobile device to answer STEM questions which are sports themed, providing a continuity between the popular and compelling power of sports and the STEM learning the project means to encourage. In this way, associations can form between the sports that form an enjoyable part of students' everyday life and the learning that will serve them better in the future.

To assess the program's efficacy, *My Sports Pulse* was implemented within a subset of middle school classrooms in Kansas City, Missouri, and Orlando, Florida. Schools were chosen to differ on variables such as ethnic background, socioeconomic status, and proficiency in math, so that the My Sports Pulse pilot could be examined across a variety of populations. A total of 76 students registered to participate between the two cities. Semi-structured interviews with teachers, parents, and students served to provide the data from which qualitative results were gathered. All participating teachers were interviewed along with a random sample of high- and low-performing students and their parents. Results from this phase of data collection for the US pilot were encouraging and provide a number of useful directions that can be implemented in future iterations to further increase the viability, utility, and effectiveness of the program. Qualitative feedback was overwhelmingly positive (Metcalf et al. 2008); the students interviewed reported satisfaction with the program overall, with 75 % indicating they would recommend the program to their friends. During a focus group interview, the reasoning for not recommending the program to friends focused exclusively on the fact that their friends "[didn't] like math or science" or would be unable to answer the questions (Fig. 6.1).

My Sports Pulse uses the seamless learning principles of Time, Space, Context, and Community – the cognitive challenges vary across time, the material may be learned and assessed anywhere the student is, the STEM material is *re*contextualized into a memorable world of sports, and the public avatar generated by the learner's progress enables the learner to engage with both their peers and their educators.

It quickly became apparent that there was value in associating the learning experiences more closely with real-world sporting events. Although students' engagement with sports has a consistently high baseline, deploying the program in conjunction

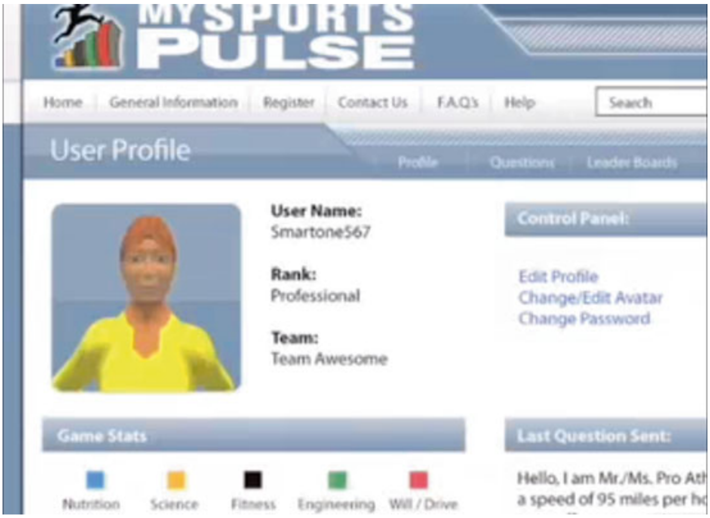

Fig. 6.1 My sports pulse

with major sporting events like the Olympics or World Cup Soccer created more opportunities for contextualized engagement. We have identified two opportunities for future study of increased contextualization. The first is the combination of fantasy sports elements and STEM problems, which could be more closely related to the outcomes of weekly games. The second would be the incorporation of learning elements into the experience of a particular game through what has been called the "2nd screen effect."

Ride and Drive

As further demonstration of the efficacy of mobile seamless learning technologies, consider the case of *Ride and Drive*, an iPad application created for use in location-based training exercises for the automotive industry.

Ride and Drive is targeted at automotive sales staff and is intended to help orient them to the features and capabilities of new vehicles. The application was deployed at sales training retreats where teams of sales people would gather for a blend of classroom instruction and test- drives. The system consists of a web-based route creation tool that allows an administrator to design a route and associate media elements with waypoints along the journey. The iPad application displays the route, and as the user drives past a waypoint, the devices play the associated media file.

The exercise was designed around two modalities. In the first case, teams of 2–4 participants would travel together in a vehicle along the route, so that the mobile device would not distract the driver. For single-passenger events, the driver would rely on turn-by-turn navigation and listen to audio messages over the vehicles' sound system.

The media files were associated with the road conditions and the locations such that users could associate the instruction with the context. For example, training materials highlighting the traction control system could be played after a sharp turn, and media describing the acceleration could be tagged to play during straight lengths of highway.

Ride and Drive applies the seamless learning principles of Time, Space, and Context. Learner information and challenge vary with time, the challenges themselves are fundamentally spatial, and the learner is immersed in the actual context of competence when executing their challenges. The mechanics of hitting a waypoint to unlock a lesson provided an engaging incentive for the participants to complete the course by structuring the exercise around specific goals and providing an interpretation for the student's experience. Instead of learning about the capabilities of the automobile in the classroom and then conducting a test-drive as a separate event, these events are combined into a seamless experience. The visceral participation in acceleration, braking, and handling is united with media elements into a continuous narrative.

This continuity of narrative can be understood as one of the primary values of context in seamless learning. The direct association of experience and pedagogy helps the student interpret the experience within the construct developed by the instructional designer.

Combat Medic

The continuity between normal life and education afforded by technology can also be affected with inexpensive low-tech approaches through the advent of educational card games. These games use affordable card decks which have familiar values and which are used in games which follow familiar rules, but which contain and use education information in a way that is integral to their use in play.

A salient example of this is the *Combat Medic Card Game* (CMCG), a tool developed at UCF's Institute for Simulation and Training which features emergent combat medical procedures printed sequentially on an ordinary deck of playing cards. These cards are much like the cards used by warfighters to play, socialize, and unwind while in the field. Extending this natural propensity of warfighters to play with cards, Combat Medic gives soldiers the opportunity to reinforce their knowledge of emergent medical procedures while relaxing, increasing the value of their time and of their attention.

To examine the effectiveness of the CMCG as a learning resource for novices to the CLS curriculum, several studies have been performed (Lyons et al. 2011).

In one (Lyons et al. 2011), the relative effectiveness of CMCG card and app modalities was compared. Overall results from this study suggest the CMCG to be an effective tool for learning, both in the card and app modalities when instructions are provided to engage with the CMCG following a flashcard-based study process. Perceived usability of the CMCG and reported engagement in the learning activity were also rated positively and did not differ between study conditions. Ratings of intuitiveness and usability also suggest the CMCG can be successfully used by a learner without the need for extensive training. This enhances the distributability of the CMCG because it can be implemented by a learner with little to no additional support needs. Future studies may explore individual differences factors that may moderate the effectiveness of each modality – e.g., younger generations are often attributed as having a greater openness to the use of novel technologies and programs.

In another study, participant experiences using the CMCG as a supplemental learning activity for reinforcing material learned within the Combat Medic were examined (Lyons et al. 2012). Overall reactions were positive, with participants indicating the cards provided an engaging way to study the Combat Medic content beyond traditional PowerPoint and classroom-based formats. A majority of participants further indicated support for the cards' future use as a supplemental learning tool within the training program and that they believed the cards held value for the learning process. However, participants' recommendations indicate the cards may provide more value if introduced early in the program. This recommendation is consistent with learning theory that suggests the declarative knowledge emphasized by the cards is essential in the early stages of learning. Additionally, it is inferred from participants' perceptions of the instinctiveness of the cards' use, as well as user comments, that additional instruction for both flashcard and game-play study modes may help optimize the impact of cards for learning. However, though specific game-play instructions were provided for those in the Combat

Medic card game condition, no specific instructional was provided to those in the flashcard condition to guide their study. Written comments from flashcard users suggested they experienced ambiguity as to how to most effectively use the cards. Future card users may benefit from more explicit instructions. With regard to the effectiveness of the cards as a study aid for supporting learning, results were inconclusive. Improvements in declarative knowledge following use of the CMCG were not detected through a comparison of knowledge test scores measured pre- and post-card use. However, the cards were not intended as an isolated learning tool, but rather a support tool to reinforce the training provided within the course. Additionally, although a greater portion of the participants in the flashcard condition perceived that the use of the cards had increased their knowledge of the Combat Medic content than those in the game condition, these perceptions were not reflected in the knowledge test results. Future research will investigate the effectiveness of different game-play modes (Fig. 6.2).

The Combat Medic Card Game uses the seamless learning principles of Space and Community – it uses Space in that the card game itself is portable and able to be played by warfighters during their tour of deployment and Community in that the games themselves are tailored to be played as a normal multiplayer activity.

Fig. 6.2 Combat medic

Virtual Family

At the other end of the spectrum, high-tech simulation technologies enable learners to experience scenarios and learning methods that closely imitate real life as it is. In conjunction with the UCF College of Medicine, METIL developed a web-based Virtual Family simulation that condenses 20 years of family practice and medical history into 4 years of medical education. Students complete various medical cases involving the different family members via a realistic, multistage process that begins with a patient interview to assess symptoms. Once the student has gathered enough information, they can request medical tests such as X-rays, MRIs, or blood tests. After a specific amount of time determined by the system, the user will receive a notification of results via email or text message and can either view them directly on their mobile device or on a desktop/laptop browser. Students may also receive case updates or notifications of a new case via voice mails recorded by patient actors, which they can access directly through a specific phone number or via the mobile/web application. Once the student has enough information, they can make a diagnosis and enter their full case notes (Fig. 6.3).

Virtual Family uses the seamless learning principles of Time, Artifacts, and Cognitive Tools. Learner information and challenge increase with time, the learner generates virtual entities (case notes, cumulative interaction histories) which persist across space and time, and the system itself helps to directly extend the learner's abilities to make and to evaluate discursively informed decisions.

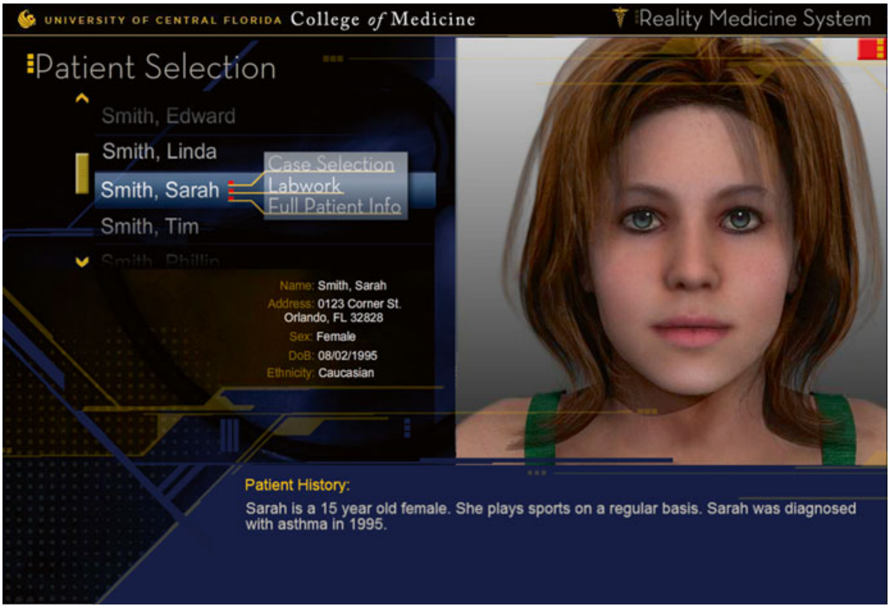

Fig. 6.3 Virtual family simulation

This progress in pedagogical possibility brings with it new challenges in instructional design. Traditional instructional technique is focused on generating an optimal classroom experience, with the material and its presentation being optimized for a fixed and static environment. Realizing seamless learning frameworks with all of its benefits will require new approaches to teaching and student activity. Generating these approaches will require increased acceptance from contemporary educational institutions, whose focus remains on classroom-setting learning.

The fundamental value of seamless learning frameworks is in how it enables education to become an *extension* rather than an *abstraction* of human life, seamlessly. Mobile devices enable people to directly extend normal experience to create learning opportunities in real time; educational games give people the opportunity to learn while they have fun; and simulation technologies engage people in realistic and practical scenarios. All of these paradigms bridge the gap between the formal and the informal, between the abstract and the practical, and between the distant and the near.

Discussion

Wong and Looi (2011) recently published a literature review of mobile seamless learning (MSL) that identifies ten different dimensions that characterize MSL approaches. This expansion from the earlier framework of six elements discussed previously demonstrates a trend toward an increasingly granular understanding of MSL. While this expanded framework is valuable for the research community, there is also value for downstream practitioners in the consolidation of findings into broadly applicable principles.

Reflecting on Seow and Looi's framework, *context* stands out as a key factor across our four case studies. In *Ride and Drive*, the instruction takes place in the vehicle, allowing the student to participate in an experience while simultaneously providing an interpretation for that experience. In *Virtual Family*, many of the interactions, for example, the voice mail messages from patients, are a pure form of simulation that achieves this synthesis of instruction and experience. *Combat Medic* and *My Sports Pulse* on the other hand are asynchronous environments and may or may not participate in a context that achieves the same level of synthesis between instruction and experience. A student may elect to use the *Combat Medic* deck during their free time or as a pre-deployment rehearsal exercise. Likewise the instruction provided by *My Sports Pulse* is grounded in thematic associations rather than experiential ones.

One observation that can be offered is that there may be an inverse relationship between the context, defined here as the distance between instruction and experience, and the student's level of engagement. Highly contextualized simulations appear to be one of the most important factors in Seow and Looi's framework. However, the long-term goal of cultivating a capacity for critical thinking depends on the ability to achieve a level of abstraction. It is possible that an overreliance on highly contextualized seamless learning techniques would tend toward instrumental rather than critical engagement. There are a host of applications where an emphasis on instrumentalism is entirely appropriate. But the work of Walter Ong is instructive here. Ong (1982) contends that literacy confers the ability to think critically, in large part because it sets the student apart from their context.

Although there is little danger at present of academic programs becoming overly contextualized, it is interesting to consider the impact of empowering next-generation educators to use context as a variable, drawing students in to engage, and drawing them back out again to evaluate their experiences from a critical perspective. One area for instructional designers to consider is the possibility of a deeper integration of formal learning elements with experiential learning programs.

It is a common practice in many disciplines to provide students with practicums and internships. The four case studies cited above suggest mechanisms for injecting formal learning elements into informal, experiential contexts. In cases such as *Ride and Drive*, it's possible to know a great deal about the student's context and deliver media that is accordingly relevant. In other cases the student's context may be less defined. One task of the instructional designer, intent on promoting seamless learning experiences, is to find ways to define a student's context in less structured environments. Finding these moments of alignment and presenting the appropriate learning resource are fundamental to promoting seamless learning.

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Part II
Technology Enhanced Seamless Learning

Chapter 7
Connecting Learning Contexts with Ambient Information Channels

Marcus Specht

Abstract The following chapter analyses the potential and shortcomings of recent technology developments with mobile and ubiquitous technologies for seamless learning. The author introduces the model of Ambient Information Channels (AICHE) to link central concepts of context-adaptive learning support and specifies a way to model context-aware and cross-context linking in seamless learning support. Based on the AICHE model, some recent technologies and educational applications of these are analysed and set in relation to the core components and processes of the model. In that analysis the key processes of the AICHE such as aggregation, enrichment and especially synchronisation are also identified as key features enabling seamless learning to be effective, efficient and enjoyable. As one example, the usage of sensor technology in the design of contextualised and synchronised learning environments is elaborated. As an important outcome, the need for more empirical evidence for the effectiveness and efficiency of seamless learning is stated.

Introduction

Mobile and ubiquitous information technologies enable information access and learning anywhere, anytime and in nearly any situation. As such this is often named as a new opportunity: the ubiquitous access to information, the seamless orchestration of learning support or the cross-context support for distributed learning activities. This integration of new technologies in everyday life situations has also dramatic consequences for the availability of information and the way humans solve problems or their daily interaction with each other (Greenfield 2006; Green and Hannon 2007). Nevertheless there are also several negative aspects considering learning and information processing linked to this. The discussion of teenagers losing focus or being addicted to new media without reflecting on their activities or not developing the skill of focused work and studying is just one of these related consequences of the ubiquity of mobile media (Rosen 2012).

M. Specht (✉)
Welten Institute, Open Universiteit of the Netherlands, Heerlen, The Netherlands
e-mail: Marcus.Specht@ou.nl

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Basically the technological support of human activities anywhere and anytime has the inherent problem of humans losing focus on situated activities in certain environments. Especially when these technologies do not take into account or adapt to the context of use (Oppermann and Specht 2000), the access to services and information in any situation can be distracting and have significant effects on affective and cognitive performance of users, linked with split attention, reduced awareness, reduced cognitive capacity or negative emotional state (Rosen 2012). Recent work on the media use of the younger generation states that there is also an increasing lack of focus, task orientation, attention distraction and lower capacity for information processing and learning. Besides other reasons this is also one of the arguments why, for example, mobile phones are often banned from the classroom. From recent research on the added value of seamless learning and the major obstacles of adoption of these technologies in the classroom, it becomes clear that this is linked to questions of the established vision of learning and educational processes, teachers' self-confidence and competence, development of didactical experiences and tooling and organisational infrastructure and leadership (Kennisnet 2013).

The development of instructional designs and an underlying conceptional model for seamless learning technologies and its tooling is a special focus of this chapter. In earlier publications the authors have developed a model for using ambient and ubiquitous technologies in educational settings (Specht 2009). A key contribution of this model is that it enables the synchronised integration of ICT based on the use of approaches from context-aware computing and adaptive educational systems. Furthermore it supports the design of applications and tooling in a dynamically adaptive and contextualised way for supporting learning that links to the current context and the dynamically developing contexts of a learner. As Sharples in the foreword (Brown 2010) puts it, a person's context can be seen as a movie and scenes of different person's movies overlap. Technology in that sense can be used to augment individual and group contexts and to bridge the different scenes in which learners create microsites for learning. Furthermore the use of context-aware computing approaches also enables the linking of learning experiences across context by modelling context as a dynamic and linking concept between different learning activities and situations.

The AICHE model simplifies the concept of context to a set of contextual metadata that describes the scenes through which users move and links between these scenes. In that sense the model does not aim at modelling the complex real-world context of learners for context-recognition or context-aware systems implementation. It focuses on the design of a techno-cognitive system in which the cognitive principles of learning are leading design guidelines for building contextual learning support taking into account the current restrictions of technology. It also aims at describing a framework of reusable system components on an abstract level that enable the simplified description of seamless and contextual learning appliances.

Mobiles, as a key technology for contextualised and personalised support of learners, are the most used new media tools of the younger generation, even more prominent nowadays than TV (Medienpädagogischer Forschungsverbund Südwest 2012a, b). Classical classroom instruction as we know it today is a place designed for focus and mostly learning in a decontextualised way following a presenter.

Therefore, the usage of mobile devices sometimes seems as a contradiction, and it is a top challenge for most educators and teachers to adapt their instructional models for opening up and bridging to informal learning outside the classroom. Nevertheless educational models such as the flipped classroom, inquiry-based learning and project-based and problem-based collaborative learning try to define new instructional designs and specify a new orchestration between the different activities in the learning process and the locations in which these activities are supported best. This is also linked to new design of physical spaces in which learning takes place (Fisher 2005). The mutual interaction between the space in which learning takes place and the bridging between these learning contexts and also the orchestration of learning support within become more and more a topic of discussion in the research community. Recent studies about the ubiquitous use of media by lifelong learners have identified preferences and habits of users accessing learning support in different rooms, spaces or situations from school to the living room (Tabuenca et al. 2013).

The younger generation is heavily using mobile technologies and their practices have changed rapidly. As one of the most important developments, the social extension of media environments can be seen. This development has been established with multiplayer gaming environments, social network services and media sharing services. These services have developed efficient ways to link to the everyday environments of the younger generation and offer opportunities to share and create peer environments with powerful incentive structures. In a literature review on the development of a classification framework for mobile social media for learning, de Jong et al. (2008) analysed a variety of contextualised learning applications and classified them according to different forms of digital content, parameters of context used for synchronisation, main purpose (adaptation goal), type of information flow and pedagogical model.

Certainly an important component towards seamless and connected learning experiences is the synchronisation between human behaviour and adaptive and flexible ICT support embedded in everyday environments. In this chapter we will argue that the processes of synchronisation (adaptation, contextualisation, personalisation) between the human learning activities in a certain context and the affordances of the physical environment are essential for the successful introduction of technology-enhanced seamless learning. Furthermore we describe some opportunities based on recent technologies to link different learning contexts and their affordances and a model on how to design such educational applications.

In the following we will first introduce the AICHE model and then give examples and the corresponding instantiations of the model for seamless and contextualised learning support.

The AICHE Model for Ambient Learning Support

The AICHE model allows describing patterns of contextual learning support in a generalised way. The model divides the description and specification of contextualised learning support in four layers. On these four layers, different system components are defined and their interrelations and the information flow are specified. AICHE uses a simple metaphor of information channels that are ambient all around us. Technically speaking the underlying assumption is that one can access any kind of information such as documents, messages, annotations and services in any given situation. Based on this assumption one has the freedom to plan for educationally sensible interactions and scaffolds as described in the phases of Luckin's model (2010) and does not need to think about technical barriers. In her model on the Ecology of Resources (EoR), Luckin (2010) looks at several changes and extensions of context from a multidisciplinary and also multidimensional perspective. Resources in a future learning ecology are distributed across devices and multiple computer-based technologies, multiple learners and a range of locations. Key components of seamless learning design are multi-dimensional user modeling and scaffolding of learning support based on the meta-cognitive, affective, and cognitive development of the learner and her environment. The instructional design in that sense is certainly formulated on an abstract level talking about available resources, filters to make these available or highlight them to the learner, specific assignments that stress the use of certain resources or the identification of More Able Partners (MAP) as Luckin specifies. The focus of AICHE on the actual implementation level allows the reuse of several components and a specification of the technical implementation of a seamless learning application on the level of input, output and relevant control structures.

The recent technological developments in sensors, mobile devices, ambient displays, mobile augmented reality, cloud-based services and educational scripting and orchestration (Specht et al. 2012a) enable the seamless integration of information channels in the user's daily environment. All information channels, users and artefacts in AICHE have a set of contextual meta-information connected to them as soon as they are instantiated. Basically this meta-information holds all contextual information about the entities' location, ID, content, environment, relations or activity (Zimmermann et al. 2007). Channels can be used to augment artefacts in the physical environment, and these artefacts are configured by the instructional logic to indicate the channel information in a special way. Artefacts also offer a kind of handle or affordance for the end user to access or manipulate the channels. Information channels can be connected to ambient displays in the physical learning environment, and they can display multimodal resources to the learner via visual, auditory, haptic, gustatory or olfactory channels (Fig. 7.1).

Artefacts, channels and users make use of sensor information to aggregate and match contextual information according to the instructional logic. As a simple example a channel and a user would have a location sensor attached to them, and the channel would continuously scan for the best way to be displayed at the changing location of the user. In an AICHE model, artefacts, channels and users are linked with a special logic or instructional design.

The description of the components of a contextual learning application in AICHE is done on four layers (Specht 2009); the goal of the layers is to have a clear distinction of reusable components in the sense of an engineering, application modelling and design approach. These layers are related to technical infrastructures and solutions engineered for context-aware systems but have been extended with specific components relevant for contextual learning.

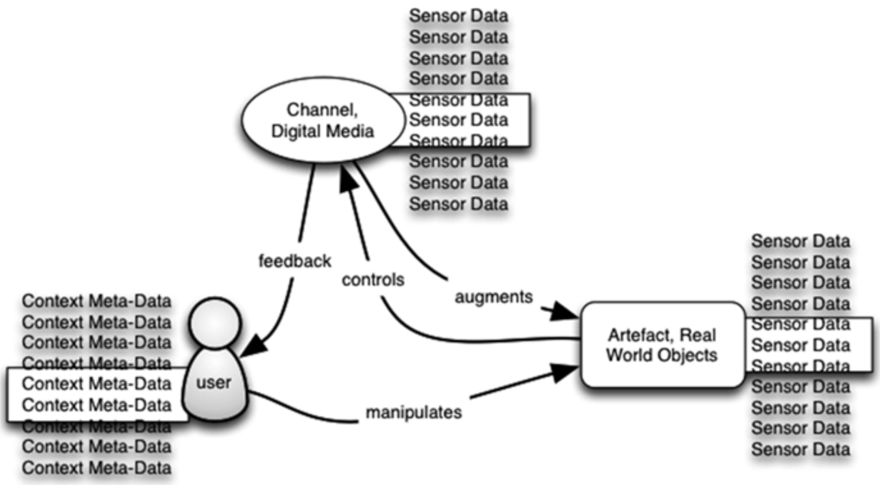

Fig. 7.1 The main entities of the AICHE model and its relations

The four layers in AICHE are as follows:

1. A sensor layer, which handles all sensor information. Key issues on the sensor layer are the integration of a wide variety of sensor types, push and pull data collection from sensors and mobile and infrastructural sensors. The sensors are the main source of information for the adaptation to the current context of use.
2. At the aggregation layer sensor information is combined into sensible entities and relations. On the one hand different sensor data is combined and converted to relevant variables and scaling for the educational application; on the other hand the enrichment of the relevant entities with sensor information is defined. Enrichment specifies the mapping of the sensor attributes to the educational variables; in that process also sensor can be used for several relevant entities. These aggregated variables can range from knowledge or preferences of users to the locations of a user or related information to the social or physical environment of a learner.
3. A control layer in which the instructional logic is specified. The logic makes use of the aggregated sensor variables and enriched entities and combines them in instructional designs. In ubiquitous learning support this layer needs interfaces to real-world objects and digital media as both are used in integrated instructional designs, i.e. the performance of a learner in a certain learning activity can influence and change the status of digital media and learning activities but also physical objects in the real world.
4. An indicator layer in which all visualisations and feedback for the user are described. Together with the sensor layer, the indicator layer holds most of the user interface components with which the user interacts.

In earlier publications we have also shown how to integrate contextual learning support with real-world learning environments in museums, industry or everyday life examples (Zimmermann et al. 2005) and described several applications based

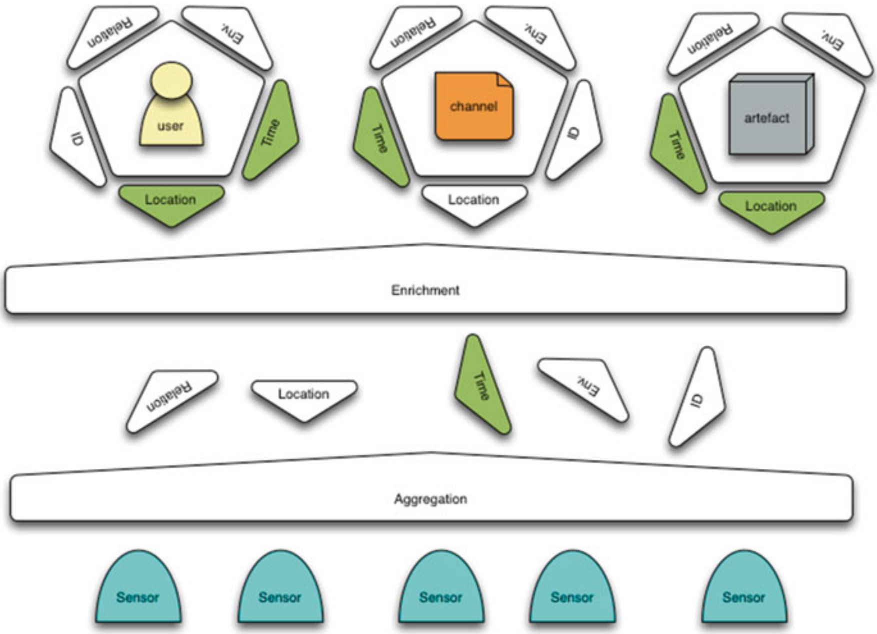

Fig. 7.2 Sensor information is aggregated, and the enrichment defines the mapping of sensor variables in the categories onto user, channel and artefacts

on these layers and the components. In the described four layers, different components are used; these are mainly sensors, channels, artefacts and control structures (Fig. 7.2).

Sensors are all kinds of objects that can measure something. This can be a thermometer measuring the current temperature or a multiple-choice test measuring the student's knowledge about a topic. For implementing contextual learning support, it is important to aggregate sensor information to make it meaningful for the learning objectives at hand. As an example the location of a GPS device carried by a user is only meaningful when it is connected to the user's perceivable environment and relevant learning tasks and objects in the environment. Aggregation of sensor data is the key process on the sensor level of the AICHE model. Aggregation of sensor data can be a quite simple process of converting scales of sensor data, but it can also hold quite complex computations of sensor input as researched in sensor fusion. Considering the relevance of sensor data to the learning objectives in most cases, an aggregation process should already take into account the interpretation of the sensor data in a meaningful way related to the objectives.

Information channels are all kinds of digital media and data streams. As a first instance one can think of learning objects but also continuous data streams can be used in channels. Basically the differentiation between sensor information and channel information is dependent on the learning objective and the educational setting. In the definition of channel information, also the data in a channel can be transformed, combined or reconfigured. All these transformations are done in the educational enrichment process, which collects aggregated data from sensors into meaningful channels for the instructional design.

Artefacts are augmented physical objects that allow users to interact with information channels. So basically artefacts can be information displays and interaction devices to manipulate channels. In this sense artefacts are also interaction devices with which the user can produce input such as keyboards, audio recorders, video recorders, text recognition engines, sense-based interaction devices and others. Control structures combine the entities and a logic description of their dependencies. Simple control structures can sequentially activate the visibility of different channels dependent on sensor information. Complex control structures can describe collaborative learning scenarios with complex interplay of sensors, artefacts, channels and user behaviour.

Contextual Metadata, Filters, Synchronisation and Framing

The components in AICHE are related to the resources in the EoR framework of Luckin (2010). In her model she distinguishes three types of resources: (a) knowledge and skills, (b) tools and people and (c) environment. The availability and usefulness of these resources are filtered by a variety of different filters, which range from formal filters like curricula to classroom arrangements and schedules. Furthermore resources and filters influence each other via relationships. In the AICHE model filters are defined on the basis of contextual information that can be attached as metadata to information channels, artefacts and users. Furthermore an AICHE model defines the mapping and dependencies between the contextual metadata of the enriched artefacts, channels and users. In the adaptation or synchronisation process, the enriched users, artefacts and channels are synchronised based on a described logic. As an example the location of an artefact and the user are matched to display a channel via an artefact in the environment of the user. The artefact that indicates the channel data can be dynamically selected by a constraint or rule in the instructional design, i.e. the selected display for indicating the channel is selected by the user location and the best possibility to display the channel in the user's vicinity (Fig. 7.3).

Synchronisation is at the core of every contextualised learning support and it is related to the scaffolding and adjustment phase in the model of Luckin (2010). On the one hand synchronisation basically is the result of a matching process, i.e. the user location is matched with location metadata of channels and artefacts. On the other hand it becomes evident that the synchronisation has to be based on instructional designs specifying the logic of the matching. Location-based learning applications are one example of such a logic in which mostly the location is used for synchronising a user, a channel and artefacts based on their location.

The added value of the AICHE model is that it enables the reuse of a logic pattern in different contexts not only in the sense of describing the instructional logic but also the necessary sensor technology, aggregation components, enrichment and entity relationship modelling and input or output channels. It therefore allows specifying a blueprint from which a contextualised learning application can be implemented

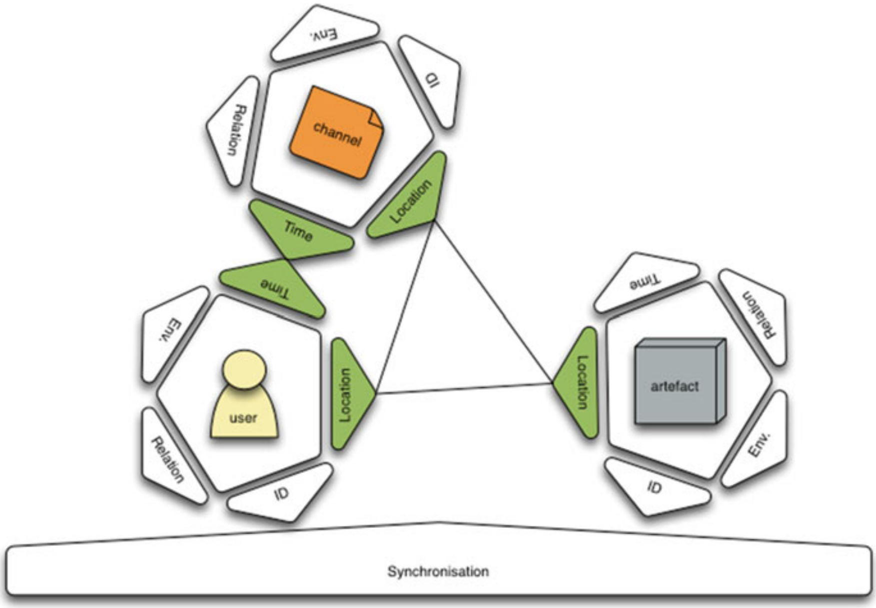

Fig. 7.3 In the synchronisation process the mapping and the dependency rules between the contextual metadata of the user, artefact and channels are specified. In the depicted example the location of the user and an artefact to indicate a channel is used to select a channel that is relevant for the current time of a user

more or less straightforward. Nevertheless the logic of the adaptation process and the synchronisation and framing processes are specified on an abstract level. This is comparable to the specification of adaptive rule systems in IMS-LD (Specht and Burgos 2007).

Additionally the display of the synchronised channels can be contrasted with relevant reference information in the instructional design. The framing process is mostly related to feedback and stimulation of meta-cognitive processes. Especially with augmented reality applications or dual-screen applications, framing gets an important role as most artefacts and real-world objects with which we learn need to be framed in the instructional context. The framing process is highly related to research that currently looks into dual-screen instructional designs such as Chang et al. (2011) in classrooms or Verpoorten et al. (2011) in fostering reflection in online environments (Fig. 7.4).

What Is Different with Contextualised Learning Support?

The AICHE model enables the implementation of contextual learning support that follows different educational paradigms and pedagogical models. In that sense it is agnostic of the instructional approach chosen. In that sense contextualised learning

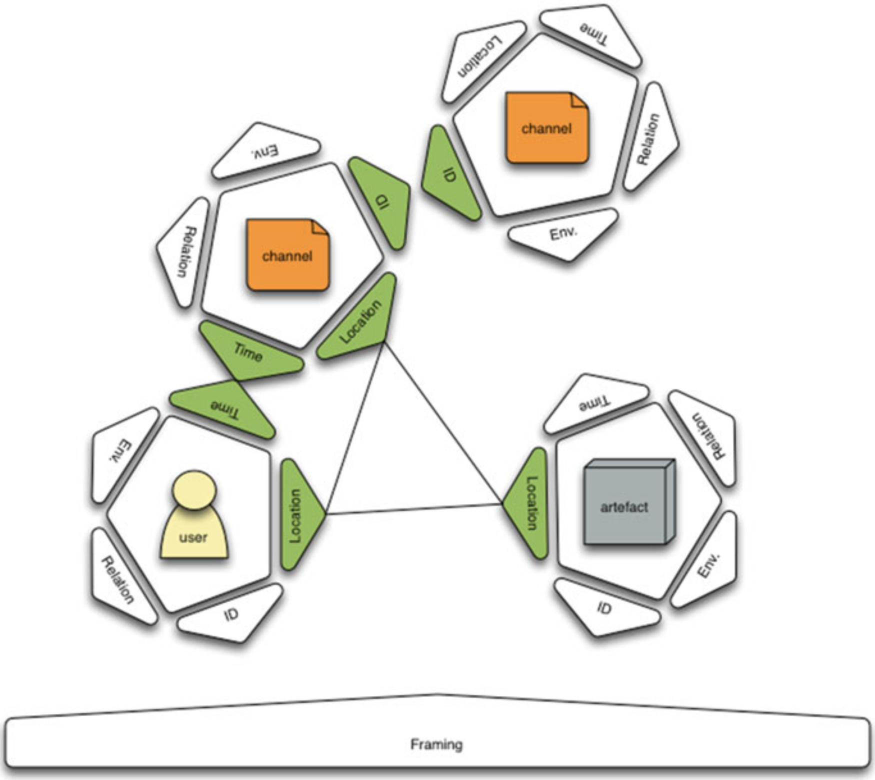

Fig. 7.4 The framing process of the AICHE model; this enables contrasting different relevant digital information based on the matching of channel metadata

support builds on principles of adaptive and personalised instruction. Adaptive methods for instruction are described and classified considering three dimensions: the adaptation mean (the source of information taken into account for adaptation), the adaptation target (the components of the system or the aspects of the instructional process that is adapted) and the adaptation goal (the educational objective of the adaptation).

Describing the difference to adaptive web-based instruction, Specht (2009) describes several extensions and qualitative changes when computer-based learning support becomes mobile, context aware and seamless:

- First, the new forms of adaptation in contextualised learning take into account sensor and environmental information additionally to classical user modelling and logging information (this is related to the sensor layer of AICHE).
- Second, new forms of adaptation targets can be defined when ubiquitous computing and ambient displays are added to the adaptive system; this is modelled in the flexible channel and artefact model.

- Third, the adaptation goals of instructional designs can include the affordances and possibilities of the authentic context of the user and enable active and collaborative learning support in context; this is modelled in the splitting of artefacts and channels in AICHE.

In that sense the AICHE model extends classical user modelling and adaptive computer-based system approaches such as Kobsa (2007) with components of the physical environment of the user with physical sensors, physical artefacts for interaction and channels for multimodal interaction and display of information. This linkage between the physical environment and the information facilities is further specified in different forms by the processes of aggregation, enrichment, synchronisation and framing.

Research from attention control and information processing in cognitive psychology stresses the fact that the context of information encoding has an impact on the recall of information and its storage in long-term memory (Tulving and Thomson 1973; Tulving 2002). Episodic memory and the importance of personal examples in problem-solving (Weber 1996) are reasons why personalisation or contextualisation of instruction in the upper sense is seen as an important factor for making learning more effective and efficient. Research on adaptive instructional systems has shown evidence of the impact of adapting learning support to individual needs, learner characteristics or the level of knowledge (Specht and Kobsa 1999). The empirical evidence ranges from higher knowledge gain from personalised hypermedia trails to a better identification of relevant features of given solutions to problems (Weber 1996). Nevertheless little research is actually done on the adaptation to the learner's physical context and the links between different contexts.

From a cognitive perspective seamless and contextualised learning technologies offer three extensions for an impact on learning outcomes:

- *Deepening of learning experiences in context*: When designing distributed learning activities, the different physical environments and affordances play an important role for a deeper learning experience. Without the synchronisation of learning support and the context of use, the added value of mobile and ubiquitous technologies is limited and will often lead to a distraction in place of an augmentation of the situated experience. Augmentation of the current learning situation with digital media and services is one principle for deepening the learning experiences (de Jong 2011).
- *Modifying latent variables in situ relevant for the learning outcome*: Quite some seamless learning solutions do have an impact on latent variables that might have an impact on the learning outcomes. A good example for these kinds of effects is either learning games that focus on the motivation to study or language learning applications that lower the barrier to actually speak in place of giving additional information (Schmitz et al. 2013).
- *Supporting learning activities across multiple contexts*: When linking different learning activities, thinking about the different contexts and situations in which those take place and the resources needed to link these activities is essential. An underlying principle of why learning situations should be linked is based on the idea of a nomadic learner (Oppermann and Specht 2000). Learning trajectories

are normally linked to several everyday environments and the instantiation of contents we learn can be found in multiple everyday environments. An example is the embedding of mathematics learned in school and the daily usage of these skills in everyday life situations (Devlin 2005).

Implementing Sensors, Indicators and Control Structures in Contextual Learning

In a recent trend scouting report on context-based learning support, Specht et al. (2012a) describe several technologies and empirical evidence on how seamless and context-aware technologies can lead to more effective and efficient learning experiences and learning support. The described technologies include sensor-based feedback systems, activity tracking and learning analytics for reflection, mobile augmented reality and ambient and situated displays. In recent research works in these areas, examples and instantiations of AICHE model can be found and will be discussed in the following. The three selected technologies and the described applications link to the AICHE model on different layers, namely, the sensor layer and aggregation layer, the control layer and the indicator layer.

Sensor-Based Interaction for Learner Support

While sensors have been used already quite some time in physical education and advanced sports training, life-logging and sensor tracking applications are more and more used in fields of applications such as health, nutrition, lifestyle, fitness, sleep or productivity. New kinds of sensor devices support users monitoring their health, weight, sleep behaviour and other parts of their daily living. Technically it is possible to track activities, geospatial movements, physical activities, social relationships and also detailed biophysiological data about learners and their daily practices. More and more of these information sources are also aggregated and combined in analytics dashboards that help users to monitor developments over time or get insights from the combination of different sensor data sources. There is an underlying question about the mechanisms and how these new forms of user tracking and the feedback based on this information can be best integrated in instructional designs and educational systems. Goetz (2011) has described the importance of feedback loops and real-time sensor feedback for human behaviour change in different domains ranging from power consumption, medication, health monitoring and other fields. As a core principle even redundant information visualised in feedback loops in the right context is an efficient mean in self-regulation.

Embedded sensor technology enables the scalable and seamless collection of data in real-world situations without requiring users to manually collect data. Via sensor information long-term performance assessment can be integrated in real life situations, but also the assessment periods can be prolonged and data can be collected on much longer time periods. Furthermore body-area networks or wearable sensor networks enable the integration of different data streams and also environmental sensor data and enable real-time tracking and analysis of physical activities and the human body. Basically sensors can make information available *in real time* and *on a micro-level*, what enables instant feedback and also formative assessment support.

Furthermore sensors enable the aggregation of multimodal sources of user tracking information ranging from movement data as used in sports, task performance or environmental sensor information. Learners can automatically create logbooks of their activities with life-logging tools or collect their results in personal portfolios. Experience sampling (Larson and Csikszentmihalyi 1983; Hektner et al. 2007) is one of the methods used to support the distributed collection of data relevant for assignments distributed across different learning situations.

Cook and Song (2009) collects different research topics on the use of body-area networks in a special issue on *Ambient Intelligence and Wearable Computing: Sensors on the Body, in the Home, and Beyond*. First, research is looking into the integration of sensors in the clothing, textiles and the related issues on power and networking. Second, new forms of algorithms and real-time aggregation methodologies are developed to evaluate and integrate different data streams and also multimodal data streams from sensors. These approaches target activity recognition of users in real time and on board in wearable sensor arrays. Third, different approaches look at the user interaction part of wireless sensor networks and how users can interact with such systems. This includes also research on the complementary usage of wearable sensor data and environmental sensor information.

Considering the function of sensors in educational systems, several basic sensors have been identified in the literature (Pfeiffer et al. 2011) and several higher-level aggregated sensor information can be identified. This sensor information can basically be used as an adaptation mean for adapting to more detailed information about the user and the current context of use (Table 7.1).

In a basic definition of adaptive systems, a main mechanism is the feedback loop. In control-system terms the input signal into an adaptive system and its impact on the system output is monitored by a sensor, and by using the sensor information, the system can adapt the adaptation target. In most adaptive educational systems, a logging of user activities and performance is used to regulate the system behaviour

Table 7.1 Low-level sensors in mobile devices and examples for aggregated sensor information based on these sensor types

Sensor	Higher-level aggregation and used function
Audio	Volume levels, frequency analysis, rhythm analysis
Video	Face recognition, lighting conditions, image or object recognition
Accelerometer	Vibration, movement, activity, agility
Magnetometer	Orientation, magnetic field, shaking, absolute orientation
GPS	Location, environment, proximity of other objects

to give the best learning support. Nevertheless in human-computer interaction and especially in learning applications, there are basically two intersecting feedback loops. On the one hand there is an adaptive educational system with a control loop as described above, and on the other hand there is an inner loop on the cognitive system of the learner; this is especially highlighted by works on the role of feedback and self-regulated learning (Butler and Winne 1995). Glahn describes the different parameters of context and the importance of these to design feedback and support for self-regulation in online learning systems (Glahn 2009). Verpoorten (2012) builds on this work and investigates the different forms of triggering reflection in online and mobile learning environments. In his works different aspects of reflection amplifiers are analysed in empirical studies, and important design features of feedback technology based on logging and sensor data in online environments are analysed.

Considering current applications of sensor technology for learning support, the AICHE model stresses the importance of sensor information for the synchronisation of different channels. In most cases found in the current literature, sensor information is used as an adaptation mean or for personal reflection of learners. The separation of two layers in AICHE into the sensor layer and the aggregation layer can be considered important to have reusable components on the control layer where sensor data from one hardware or software sensor can be used for different attributes of entities in modelling the instructional logic. In general especially in seamless learning environments, the synchronisation of the different learning resources and services requires sensor data to be more efficient, effective and enjoyable.

Mobile Games and Inquiry Support as Control Structures

Some research works in the last years explored the field of mixed reality and mobile serious games. Schmitz et al. (2012) give an overview of the design patterns used in mobile serious games and the educational effects thereof. Different educational effects of mobile learning games have been researched mostly in the areas of cognitive and affective learning outcomes.

Mobile serious games offer the opportunity to link educational activities to physical locations and to connect different physical location and learning contexts via an educational script. ARLearn is a mobile serious gaming framework that enables educators to connect digital information with different contexts and also trigger interaction and data collection in different physical locations. Rules and dependencies between different activities can also be specified. The framework has been used to develop different forms of single and multi-user games as described in Ternier et al. (2012).

The main forms of mobile serious games based on the ARLearn framework can be described in AICHE model terms as the following:

- Educational field trips and field work support: Learner's location is matched to contextual metadata of the available digital resources, and depending on the educational approach, more or less dependencies between the different locations and activities are specified and used in the instructional logic. In some cases teams and group dependencies are specified to present follow-up information only if certain tasks have been fulfilled or other team members have completed their activities.

- Artefacts in the real world are used as triggers to enable access to certain information or trigger learning activities such as data collection or reflection. The identification of the physical objects in the learner's environment can be used to trigger either pedagogical interventions into a physical context (like a reflection question connected to a physical object) or inject related digital information in the current learning context.
- Ambient displays for situated interaction or feedback in context. In this scenario indicators in the users' physical environment are used to indicate relevant information for changes in the current learning context. This can either support problem-solving or also trigger reflection by giving related information for the current learning activity.

In recent studies and also the integration of mobile sensor technology, the interaction with real-world objects and the usage of ambient displays have been tested to support cross-context learning (see also this book Chap. 20 by Kalz et al.). The cross-context learning scripts implemented based on the ARLearn framework support time- and location-dependent triggers of information to learners, context-specific task assignments, notifications for group assignments and context-specific reflection support. The main features necessary in the ARLearn framework for supporting cross-contextual learning activities is a context-specific notification framework and a data collection component.

For each learning activity in a cross-context script dependencies can be specified in ARLearn. These dependencies can specify conditions for triggering action based on the current user context as time or location, the activities of a user as the scanning of tags, or the learning activities of other learners. Based on these dependencies notifications can be sent out to different clients (indicators) such as the user's mobile phone or an ambient display in a public location.

User data collection supports the linkage of different contexts as data is collected for personal documentation of experiences in different situations related to an ongoing learning project. Therefore a second key component in the ARLearn framework is the data collection, which enables the collection of audio, video, text and numerical data from mobile devices which are aggregated in the back-end services of ARLearn. Based on this research the weSPOT project has recently started to build a toolkit for mobile inquiry-based learning in which a personal inquiry is supported by mobile notifications and data collection features in ARLearn.

Different models have been proposed for structuring mobile inquiry-based learning and designing technology support. The weSPOT project has developed a recent approach for the design of seamless technology support for creating and operationalising inquiries of different types, collecting and analysing evidence and reporting and collaborating on inquiries (weSPOT consortium 2013, Specht et al. 2012b).

Based on the inquiry model, a set of tools for seamless support of inquiries has been designed and is under development. Based on a back-end inquiry, engine mobile data collection tools, tools for data analysis and interpretation and also collaboration and tools for learning analytics are under development. Basically the weSPOT project toolset aims at a seamless inquiry support for the following:

- Creating an inquiry space for different forms of inquiry ranging from confirmation inquiry to open inquires. This should support both teacher-initiated inquiries in a classroom context and also mobile inquiries from individual experiences and "wonder moments".
- Seamless integration of data collection in the field and inquiry hypotheses and collaboration around evidence collection.
- Seamless facilities for performance reporting and learning analytics; this will include collaborative data manipulation based on tabletop and interactive whiteboard applications and also reporting and reflecting tools for individuals.
- Reporting and documentation of inquiry results.

The seamless support of mobile inquiry-based learning is a good example bridging several seams according to Wong and Looi (2011) and also deepening learning experiences in context as well as bridging between different contexts. Considering the AICHE model, this integrated all layers from the sensor for monitoring the current context of use, aggregating sensor values in collaborative and personalised scripts, connecting different learning contexts by using contextual dependencies and notifications in educational scripts and also embedding and distributing indicators of information such as mobile phones, personal computers, interactive whiteboards and public displays.

Augmented Reality and Situated Displays as Indicators

Mobile augmented reality gives new opportunities to enrich the learner's physical environment with digital augmentations. Specht et al. (2011) describe different educational patterns and collect evidence on how applications in the fields of architecture, visual design, history, biology and astronomy can take advantage of augmented e-books, collaborative manipulation of 3D models or location-based filtering of information in the vicinity of the learner. The described effects are mostly based on the visualisation of merged or interlinked digital information and real-world objects, and therefore an integration of the underlying concepts can be done on a concrete real-world context.

The augmentation of the learner's context is based on the AICHE model and can be described by its contextual filters and the type of interactions of learners. The most common models use the location of the user to embed relevant information sources in a head-up display (HUD) in which the user has a kind of look-through perspective in which different layers can be shown. Location-based filtering in mobile augmented reality (AR) mostly takes into account location, compass and time information.

Another approach to embed learning support in real-world situations besides mobile augmented reality is ambient learning displays (Börner et al. 2013). Following Wisneski's view (Wisneski et al. 1998) on ambient displays, who basically defines ambient displays as embedded in the environment close to the user and presenting information related to the user's current context, awareness can be deduced as a main instructional characteristic of ambient displays. To grasp the application possibilities of ambient displays in learning contexts, this concept needs to be further exploited, e.g. by accomplishing this perspective with the concept of situational awareness (Endsley 2000). Endsley defines situational awareness as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future". Following this definition the author presents three levels of situational awareness that can be used for classification, namely, perception, comprehension and projection. Perception is related to situational cues and important or needed information, comprehension relates to how people integrate combined pieces of information and evaluate their relevance, and finally projection relates to how people are able to forecast future events and situations as well as their dynamics. Especially on the higher levels of situational awareness, the type and characteristic of feedback given by the ambient displays play an essential role for their effectiveness, impact and behavioural change capabilities and thus are another important instructional characteristic that can be deduced. In that sense also the concept of providing (instructional) feedback needs to be incorporated, whereas Mory (2004) provided an extensive research review.

The question on how to design learning support that is efficient and/or effective in the filtering, selection and presentation of relevant cues, information or digital media based on the real-world context of a user seems to be essential. In the AICHE model this process is described in the enrichment of channels, artefacts and users with contextual metadata and also in the process of synchronisation between the different contexts for adaptive instruction and personalised user experiences.

On the indicator layer the way a feedback loop towards individual users or groups of users is designed is essential. This is also supported by recent research and also the need to have flexible access to different displays in educational scripts for different forms of orchestration of feedback in learning environments. Augmented reality in this sense is a highly flexible display technology enabling to embed channels in the user's physical environment and dynamically generating and synchronising the channel to the user's changing context.

Summary and Discussion

In this chapter the current developments of mobile and ubiquitous technologies and their potential role for learning have been discussed. Besides the argument that ubiquitous and seamless learning support holds great potential, also some current shortcomings, the barriers for adoption and critical reflections on these technologies have been discussed. As a main outcome of these reflections, the need for synchronisation and integrated use of different mobile and ubiquitous technologies based on educational scenarios and didactical models can be stated.

In a second step, the AICHE model has been introduced, and the different layers of contextualised learning support that can be modelled in AICHE have been linked to the different technologies and their characteristics. Embedded sensor technology builds the base layer of contextualised learning, which enables the aggregation and integration of personal and environmental sensor data into feedback loops and adaptive educational systems which adapt to the learner and his/her environment and also to the current level of expertise and competence. The core features of a control layer building on this sensor information enable the definition and description of dependencies and educational scripting for adapting to the current context of use and also supporting cross-contextual learning support. As examples for technologies in the indicator layer of AICHE, mobile augmented reality and ambient learning displays have been presented, and the linkage of all layers in AICHE has been illustrated with examples from mobile inquiry-based learning and mixed reality serious gaming (see also MINDERGIE in Chap. 20, this book).

The AICHE model in its current form can be seen more as a technical framework for differentiating and structuring different components of contextual and seamless learning support. By this differentiation and the clear definition of these components, the main contribution of the model at the moment is the provision of a framework for building reusable components of seamless learning support on the sensor, control and indicator levels and therefore enabling the flexible and low-effort prototyping for seamless learning. Furthermore this can be used together with a software framework such as ARLearn to build and evaluate prototypes to better understand the role of the different processes described in AICHE such as aggregation, synchronisation and framing.

For future work the evaluation of prototypes for seamless learning in laboratory and field studies is essential to understand the different components in these systems and the potential for educational outcomes. The current chapter already links to some recent studies in the fields of sensors, control structures and indicators as augmented reality and ambient displays. The difficulty of evaluation of ubiquitous and seamless technology is also inherent in its definition as these technologies should be embedded and linked to authentic everyday learning contexts. Nevertheless there are opportunities to evaluate specific research questions in experimental settings and also in more ecologically valid field studies as some of the referred studies demonstrate.

The main goal of the further development of the AICHE model is the support of educational technology designers of future technology-enhanced seamless learning spaces. Therefore design guidelines for different model components such as sensors, instructional logic (control layer) and feedback loops (indicator layer) are identified in ongoing research and are collected in design guidelines based on empirical results linked to the AICHE model.

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Chapter 8
A Resource Organization Model for Ubiquitous Learning in a Seamless Learning Space

Shenquan Yu and Xianmin Yang

Abstract The proliferation of advanced learning technologies, such as integrableware, learning object, and learning design, have prompted the development of strategies to enhance the semantics of learning resources. Such strategies are characterized by the sharing of procedural information (posts, notes, questions, assignment, etc.) during the learners' learning process, the perpetual evolution of resource content via collaborative editing, and the creation of a new resource construction mode based on Web 2.0. In this paper, a novel learning resource framework known as "learning cell" is proposed. This framework is intended to enable generative, evolving, intelligent, and adaptive learning resources in future u-learning. Learning cell provides a design model for future seamless learning spaces supported by pervasive computing technology.

Introduction

With the development of pervasive computing (Weiser 1991) and sensor networks, the digital space is increasingly converging with the physical space. This convergence gives rise to a ubiquitous information space that covers both the real world and virtual world. Thus, a seamless learning space (Chan et al. 2006) can be constructed to enable ubiquitous learning (u-learning). Indeed, learning processes are becoming increasingly context related and human based, enabling opportunities of collaborative and lifelong learning.

However, the emergence of new technological environments alone does not necessarily facilitate a good learning performance. Effective learning is inseparable from well-constructed learning resources. While current research on seamless learning has mainly focused on conceptual models, context computing technologies, and

S. Yu (✉)
School of Educational Technology, Beijing Normal University, Beijing, China
e-mail: yusq@bnu.edu.cn

X. Yang
Institute of Education, Jiangsu Normal University, Jiangsu, China

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supportive environments (Li et al. 2005; Hong and Cho 2008; Tan et al. 2011), we as a field need to create new schemes of resource organization to make sure that learning resources are available anywhere and on demand and can address the needs of u-learning. Existing learning technologies focus on the sharing of learning resources in stand-alone platforms. The sustainable development and evolution of learning resources, the dynamic and generative connections among learning resources, and the dynamic relationships between learners and teachers via learning resources are overlooked. Following the development of integrableware (Li 1997), learning object (ADL 2000), and learning activity (IMS 2003), enabling co-construction and sharing of u-learning resources have become a core research focus among scholars.

Effective ubiquitous learning relies upon the creation of an intelligent seamless learning space. The basic elements of such an environment consist of a communication network, context-aware intelligent learning terminals, learning resources, and education cloud-computing services. The existing single-point-centralized storage and hierarchical directory organization of learning resources cannot meet the needs of pervasive, context-aware, and timely learning spaces (Yu 2007). New demands and challenges are proposed to adapt to u-learning:

1. U-learning requires contextual and adaptive learning resources. Seamless learning spaces would support the individualized needs of learners and supply recomposed learning resources that are adaptable to different learning terminals.
2. U-learning requires a large amount of learning resources. To provide ubiquitous and on-demand learning resources, u-learning needs an open and distributed resource model that enables everyone to construct and obtain learning resources. The pieces of contribution that learners made can develop into an unlimited extensible resource chain, which in turn satisfies the extensible and personalized demands for future learning activities.
3. U-learning requires evolving learning resources. Ubiquitous learning resources should be in real time to reflect the latest developments in related areas and meet the actual real-time needs of learners. U-learning needs to keep track of information generated during the learning process, which serves as nutrients for the evolution of resources and reflects the history of knowledge construction. That is, learning resources should evolve during the process of learning by absorbing the collective wisdom of learners. The traditional static and closed organization of learning resources need to be changed into one that is dynamic and open to ensure the self-evolution of learning resources.
4. U-learning requires learning resources that are integrated with learning activities. Learning does not solely consist of obtaining new information. It also requires effective internalization by providing learners a chance to participate in learning activities.
5. Above all, u-learning requires "human" resources and the sharing of social cognitive networks. Interaction in u-learning is not solely restricted to the interaction between learners and materialized resources but also includes participation in learning processes. Here, materialized resources are viewed as communication media for learners to take in collective wisdom, construct social cognitive networks, and obtain sustained channels to acquire knowledge.

In response to the above demands, this paper proposes a new scheme—learning cell—to describe and package learning resources (Yu et al. 2009). Learning cell is a new model to organize and share learning resources to support the construction of a seamless learning space.

Learning Cell Framework

Concept

Learning cell is a digital learning resource characterized by generative, open, self-evolving, connective, social, micromation, and intelligent features. Learning cell adopts dynamic elements and structure as well as cloud storage to adapt to u-learning. The meaning of "cell" is multifold:

- Component
  Components reflect the standardization, micromation, reusability, and integrality of learning cell. From this perspective, the design concepts of learning cell and learning objects are similar.
- Initial
  Learning cell would experience a development process during which it would be initialized, grow, strengthen, and increase its durability. Learning cell changes during the use process rather than remain unchanged. The evolving and germination characteristics of learning cell distinguish it from learning object.
- Neuron like
  Learning cell can perceive environments, adapt to terminals, and generate rich connections. The connections between learning cells and humans form social cognitive networks. When these networks grow to a certain scale, the social intelligence aspect takes effect, which also serves as an essential distinction between learning cell and learning object.

Learning cell is advanced mainly by introducing the temporal dimension and interpersonal cognitive networks into learning resources. Learning resources are no longer static, but grow over time. Information is stored and updated during the evolution, including version updates, historical records, and procedural information (posts, notes, questions, assignment, etc.). Relationship networks are constructed among participating persons as well as between knowledge and persons. These networks not only help students with their knowledge construction but also aid in sharing collective wisdom during the process of knowledge evolution. Learning cell provides learners with resources related to learning content; moreover, it provides a series of content-focused activities, tools, and social networks. As a result, learning cell is a channel that supplies learners with sustainable information and knowledge.

U-Learning Process Based on Learning Cell

As shown in Fig. 8.1, u-learning can generate a seamless learning space via the coordination of cloud-computing and multimedia technologies.

Whenever users encounter problems or become interested in something, their needs in the particular context can be perceived by the intelligent terminals and sent to educational cloud-computing platforms with pervasive communication networks. The platforms would perform a search, computation, and transformation according to the demands of users and individualized information to select the appropriate learning content for the use and attach the content with learning services and knowledge networks. Learners would be able to contact other learners interested in the same content, editors, and even experts to form learning communities, where they not only obtain the most authoritative knowledge in the field but also build relationships with the experts. This learning mode is not an image of traditional learning in classrooms with one teacher and many learners, but a type of 1:1 or even n:1 learning, in which many authoritative experts as well as collaborators serve as teachers for one learner.

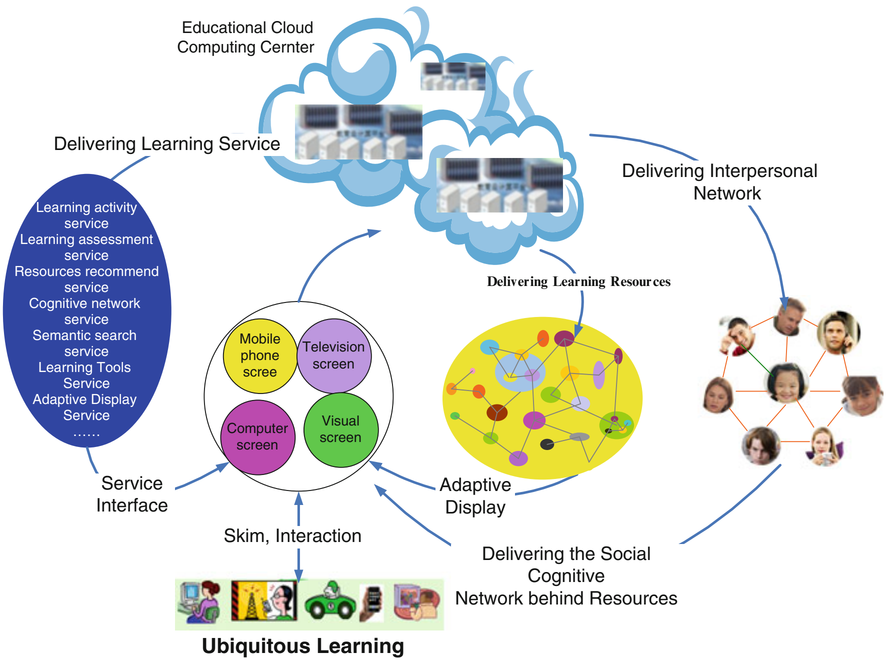

Fig. 8.1 The ubiquitous learning process based on learning cell

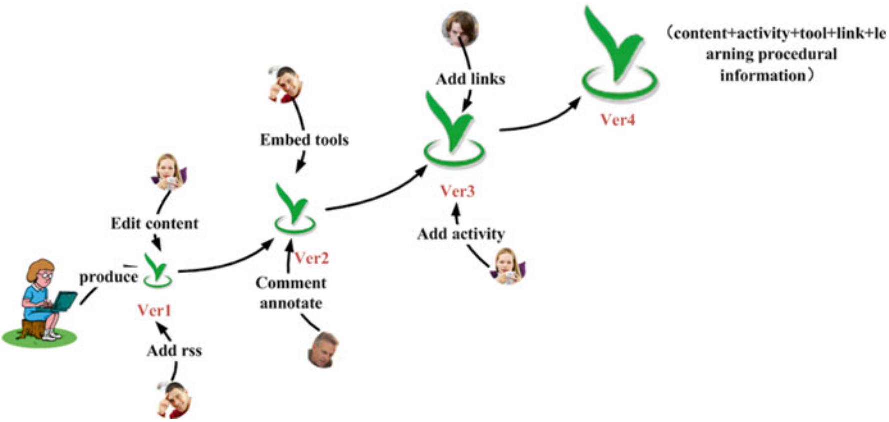

Fig. 8.2 Content evolution of learning resources

Core Features of Learning Cell

To further develop learning object and learning design specifications, learning cell features the following three unique properties:

1. It proposes a semantic-based aggregation model that controls the orderly evolution of resources according to semantic information.

Content is the key component of learning resources. An open-content organization enables multiple users to collaboratively create and edit content, which allows this content to be updated and developed (see Fig. 8.2). Users first generate learning resources and invite collaborators to edit the open content. As the content evolves, more users familiarize themselves with the content and add comments and annotations to it. With time, the content is updated as the collective wisdom of users grows until a high-quality version is generated that satisfies the demands of learners. At present, most open content evolves via collaborative editing, and a version control mechanism is used to protect the content.

The most important distinction between learning cell and learning object or SCORM-based online courses is the application of a semantic network and ontology technology, which causes learning cell to behave like an organism that grows and evolves via the control of the internal "gene." Besides as an independent learning unit, each learning cell could serve as a node in resource networks that would connect with other nodes according to certain rules (Fig. 8.3). Learning cell supports the semantic-based network aggregation model, which is different from the hierarchical aggregation model. It can aggregate different learning materials into learning cells as well as different learning cells into even bigger knowledge groups or knowledge clouds (Fig. 8.4).

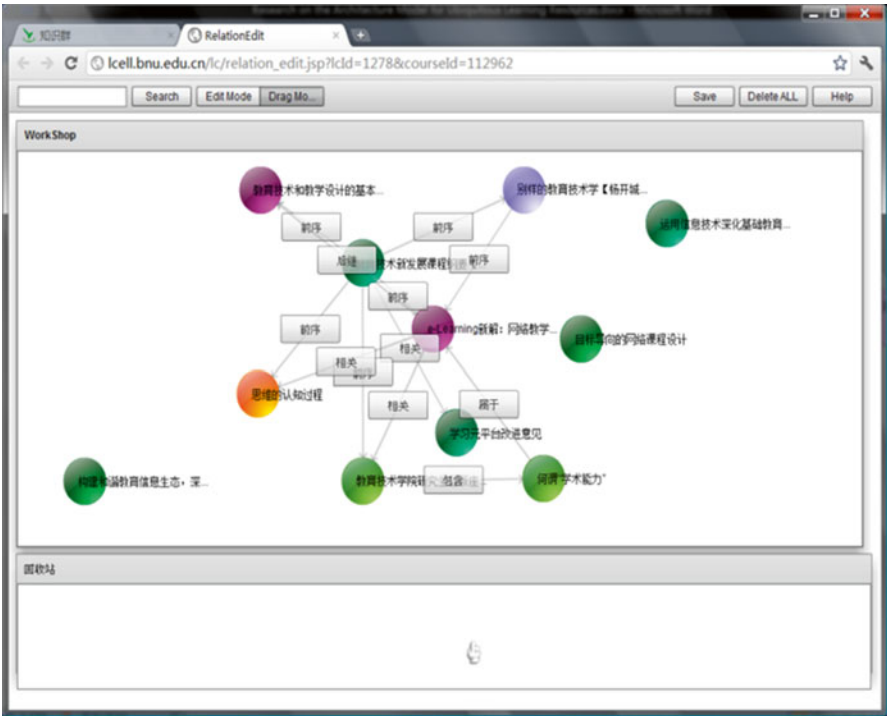

Fig. 8.3 Visualized editing of semantics network

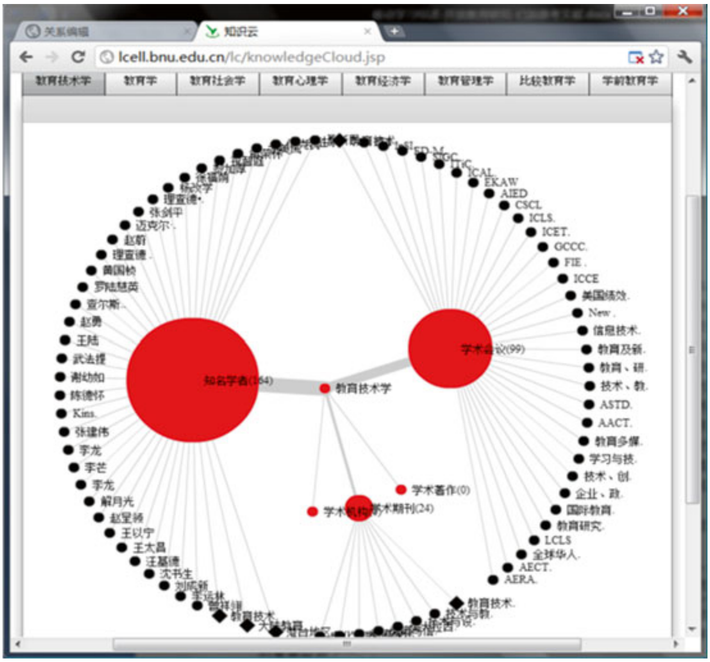

Fig. 8.4 Visualized navigation based on semantics

Semantic-based aggregation has three meanings:

(1) Learning cell could connect with other similar learning cells based on field ontology to form an extensible semantic web on certain subject over time. A learning cell could enrich its content in time by acquiring updated information from connected learning cells. (2) The learning content in learning cell is not static. It evolves during the process of application according to semantic development. According to the field knowledge ontology, learning cells can grow and divide similar to a neuron; it could search for other learning cells and resources on the same subject to form dynamic connections. (3) Learning cell grows in a structured manner. The learning content in learning cells evolves according to the structure of the field semantic ontology, which controls the development directions for learning cells, just as genes control the development of an individual.

2. Learning cell proposes a computing model for cognitive networks, which forms during the interaction with learning resources.

Traditional learning resources are limited to the sharing of physical learning resources without the consideration of people. However, learning resources in learning cells include not only physical resources but also people connected by physical resources. Constructing computing models for cognitive networks based on the interaction data of learners is important to share dynamic and social cognitive networks (Fig. 8.5).

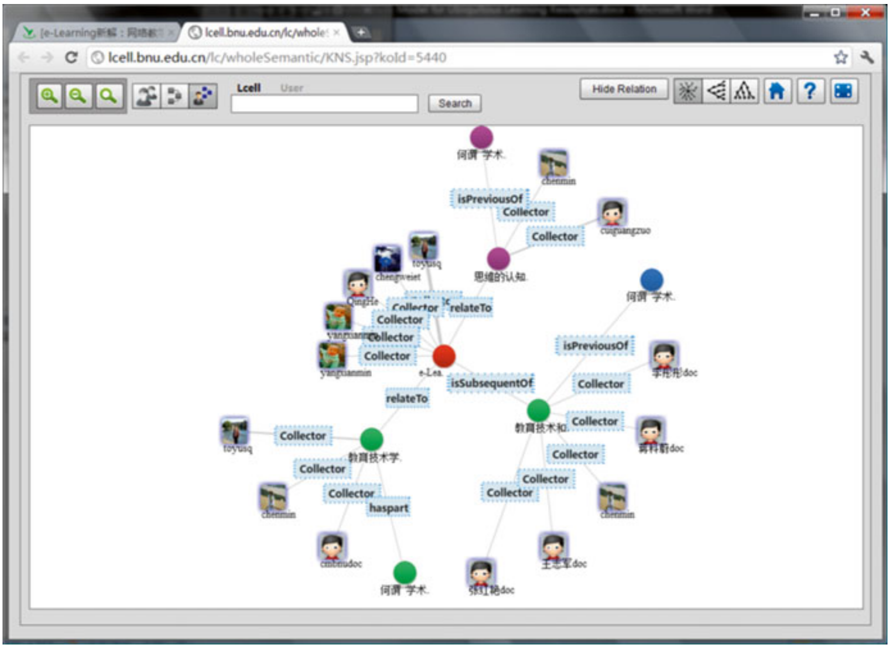

Fig. 8.5 Simulation of social cognitive network

Because learning content converges with the wisdom of all learners, the combination of physical resources and people would create a dynamically evolving and developing social cognitive network. Learners could acquire not only existing knowledge but also the learning methods and knowledge-acquiring channels. Once a network is formed between the knowledge and learners, learners would be able to continuously obtain the knowledge they need via such a network, which is characterized by the same concept as social construction and distributed context awareness.

Therefore, the social characteristics of future learning resources would gradually strengthen. In u-learning, learning resources should also serve as the bridge to connect learners in addition to being the carrier of knowledge. The cognitive network attached to learning resources is an indispensable attribute for future learning resources.

3. Learning cell provides an open and dynamic storage model for learning resources and a resource aggregation model to support context-aware learning.

The core feature of u-learning is context awareness. U-learning could provide different learning services according to different learning contexts, i.e., perceive the demands of users with intelligent learning devices and offer the most suitable learning modes and services. To realize this learning framework, we must improve the perception ability of learning terminals and redesign the aggregation model for learning resources to adapt to different contexts.

The context awareness of learning resources lies in the following two aspects: (1) intelligent adaption to learning terminals and (2) adaptability of learning content. Learners can obtain resources according to their actual needs in the most appropriate way.

The current description of learning resources is based on static-structured metadata, which cannot provide rich descriptions for different disciplines and application scenarios. This type of description and organization mechanism cannot meet the needs of context-aware and individualized u-learning. To ensure that learning content is dynamically aggregated and self-adapted, the static structure model must be changed such that each part of the learning content is organized in a process-oriented logical structure and dynamically generated.

Learning cell adopts the cold storage model of u-learning. The structure of learning content and the learning content itself are separated in distribution as illustrated in Fig. 8.6. Learning cell consists of dynamically structured resources composed of metadata, ontology, content, activity, evaluation, generative information, and multi-format data. These components connect with "education cloud services" via numerous service interfaces (such as learning activities and evaluations). "Education Cloud Services" contain an immense amount of learning resources and various related records, including activity records, editing records, evaluation records, use records, learning communities, and other information generated during learning processes.

The structure of learning content is learning process oriented, which describes objectives, conditions, and the process of learning as well as the requirements of learning content. The learning content itself can be stored in resource servers all over the world.

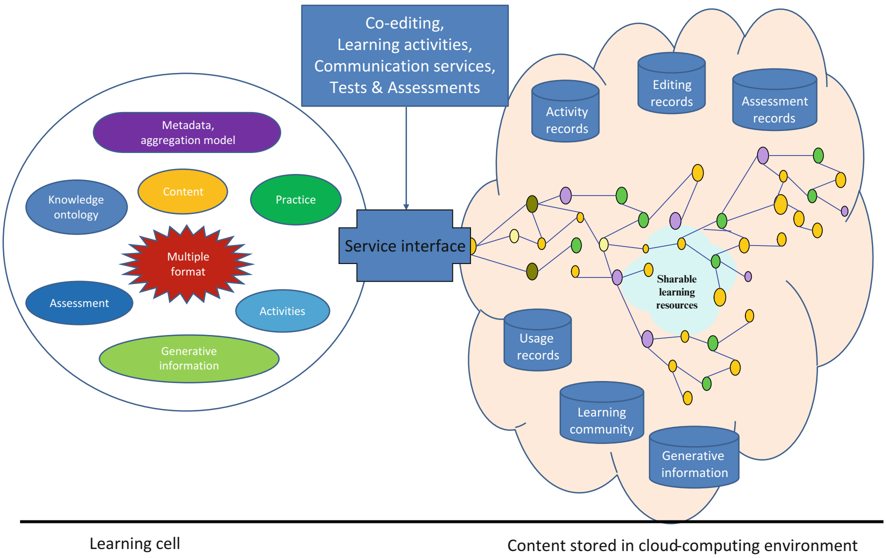

Fig. 8.6 Cloud storage model of learning cell

These resources are developed, shared, and stored in different nodes. Different resources connect to each other via dynamic semantics. When learners enter u-learning environments, they access the dynamic structure of learning content. The education cloud service system would search for the appropriate content to fill that structure according to context parameters. The structure of the same learning content generated by the system depends on the learner. When learning cells are accessed in different contexts, the aggregated learning content is different to meet individualized needs of different learners.

Learning Cell Runtime Environment

The success of learning object relies on a SCORM-supported learning management system and an IMS-LD-supported learning platform. Learning cell operates independent of a specific supporting environment. The architecture of the learning cell runtime environment is shown in Fig. 8.7. Key components include the message transfer controller, resource locator, repository, learning cell runtime engine, active adaptor, and learning service interface.

The *message transfer controller* receives user request information from the U-network, analyzes the information, and decides where to send the information.

The *resource locator* manages resource indices, searches learning resources at the requests of users, and locates the resources in the repository.

The *repository* stores learning cells and other resources, including generative information, semantic relationships, user information, and information about various devices.

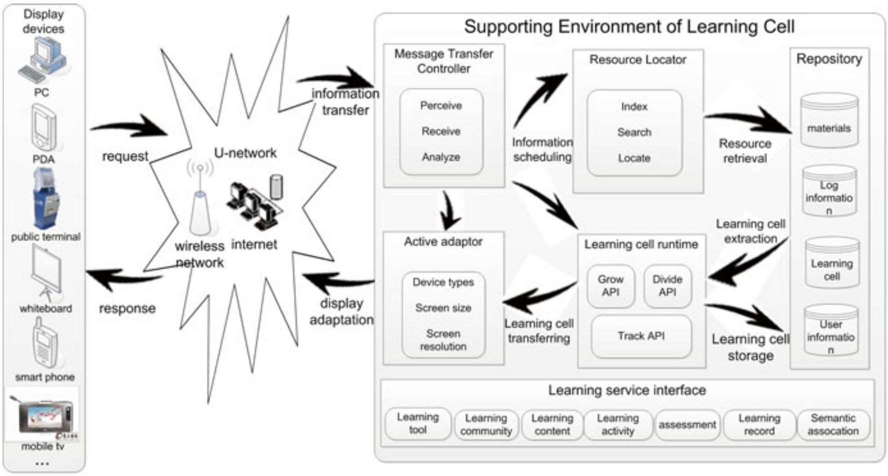

Fig. 8.7 Architecture of the learning cell runtime environment

The *learning cell runtime engine* manages the information exchange between learning cells and the external environment; it consists of a series of APIs, including the learning cell grow API, the learning cell divide API, and the learning cell track API. Via this engine, the content of learning cells can evolve, resources can be aggregated based on semantics, and the learning cells themselves can divide and grow.

The *active adaptor* receives device information from the message transfer controller; analyzes device types, screen sizes, and screen resolutions; and transforms the content into the most appropriate format for display on devices.

The *learning service interface* provides users a series of learning services, including learning tools, learning communities, learning content, learning activities, learning assessments, learning records, and semantic associations. Learners can use these interfaces in the U-network and access learning support services from any location and at any time.

A U-network is a ubiquitous network that supports u-learning; it is accessible via the Internet, wireless communications, and digital TV networks, to which users can easily connect with a device. A U-network manages the data transfer and device communication that are necessary to transfer content among learning cells. Various display devices, the U-network, and the learning cell runtime environment work collaboratively to form a learning cell-based, seamless learning environment.

The learning cell runtime environment is based on J2EE and SOA and can be divided into four layers: the repository layer, the service layer, the application layer, and the display layer.

The *repository layer* stores various data from the runtime environment and includes (1) a resource repository, which stores all of the resources, including learning cells and knowledge groups; (2) an ontology repository, which stores all of the knowledge ontology in the environment, including predefined ontology and user-generated ontology; (3) a user information repository, which stores information such as user portfolios and trust degrees; (4) an activity repository, which stores information such as discussions, voting patterns, and reflections; (5) a tool repository; and (6) a log repository, which stores logs from learning cells, knowledge groups, learning activities, and user operations.

The *service layer* provides various services based on data from the repository layer, including learning activities, learning assessments, learning tools, version controlling, ontology editing, resource management, resource aggregation, resource indexing, format matching, and learning activities.

The *application layer* provides applications to users by calling services from the service layer. The applications include learning cells, knowledge groups, knowledge clouds, learning tools, personal space, and learning communities, all of which offer varied learning experiences.

The *display layer* automatically converts the format of learning cells according to the information provided by the display devices, which could include digital TVs, computers, smart phones, public information terminals, and live telecasts, so that learning cells can be properly displayed on different devices.

Learning Cell System Development

Researchers have developed several types of ubiquitous learning systems. Ogata et al. (2008) developed the basic support for ubiquitous learning (BSUL) system to support classroom teaching and learning. Hwang et al. (2009) developed a context-aware u-learning system to guide inexperienced researchers to practice single-crystal X-ray diffraction operations and proved its systematic nature, authenticity, and economy. Liu et al. (2009) developed an environment of ubiquitous learning with educational resources (EULER) based on radio-frequency identification (RFID), augmented reality (AR), the Internet, ubiquitous computing, embedded systems, and database technologies to learn outdoor natural science. Huang et al. (2012) developed a ubiquitous English vocabulary learning (UEVL) system to assist students in carrying out a systematic vocabulary learning process in which ubiquitous technology is used to develop the system and video clips are used as the material.

However, all of the above u-learning systems were not meant for addressing the need of designing special learning resources for u-learning. They adopt traditional learning resources, such as learning object, CAI courseware, video, test, etc., which cannot meet the demands of u-learning development (Yang et al. 2013). The learning cell system (LCS) is an open learning platform developed for u-learning based on the concept of learning cell. It supports collaborative knowledge editing, knowledge aggregation, and evolution, multiple-level interaction, and multidimensional communication. Specifically, LCS allows the orderly evolution of resources, facilitates shared cognition networks and the collaborative construction of ontologies, and provides open service tools. LCS can be accessed at http://lcell.bnu.edu.cn. Since it was inaugurated in May 2011, 10747 users have registered, 57705 learning cells have been created, 66 learning applets have been generated, 3,425 knowledge groups have been formed, and 83 learning communities have been formed (as of Nov 15, 2013) (Fig. 8.8).

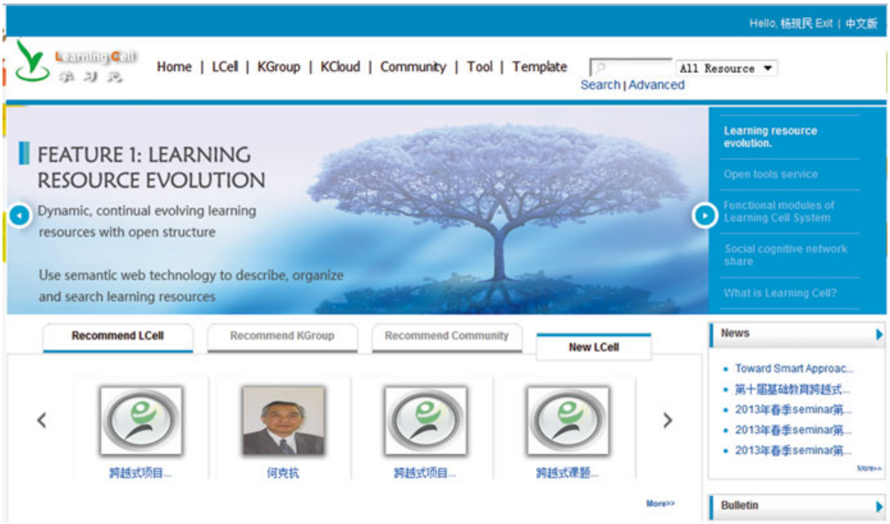

Fig. 8.8 Screenshot of the LCS home page

Functional Framework of LCS

The functional model of the LCS is shown in Fig. 8.9. Its main functions are knowledge group (KG), knowledge cloud (KC), learning cell (LC), learning tool (LT), personal space (PS), and learning community (LCM).

The LC function assembles all of the learning cells in the environment. Each learning cell is a resource entity, which can be a lesson or a knowledge point. A learning cell contains not only learning content but also learning activities, KNSs, semantic information, generative information, and multi-format data. A learning cell can also be an independent learning resource used by learning communities. Different learning cells on a related subject can be gathered into a knowledge group. Learning cells can introduce related assistant learning tools to support u-learning. Learning cells are available in multiple formats, such as web pages, e-books, concept graphs, and 3D models (Fig. 8.10).

To control the quality of learning resources, LCS provides a scoring function that allows anyone to comment and score any learning cells. Those learning cells with lower scores that have remained unimproved for a long time (over than 2 month) will automatically be removed from LCS. Furthermore, a two-way interactive feedback model (TIFM) (Yang et al. 2014), which is a kind of trust evaluation model, was also adopted in the LCS to judge resources and the credibility of users. Additionally, an incentive mechanism, including the rank of title, virtual and real awards, and rank of contribution degree, is implemented in the LCS to attract more users to engage in knowledge creation and sharing.

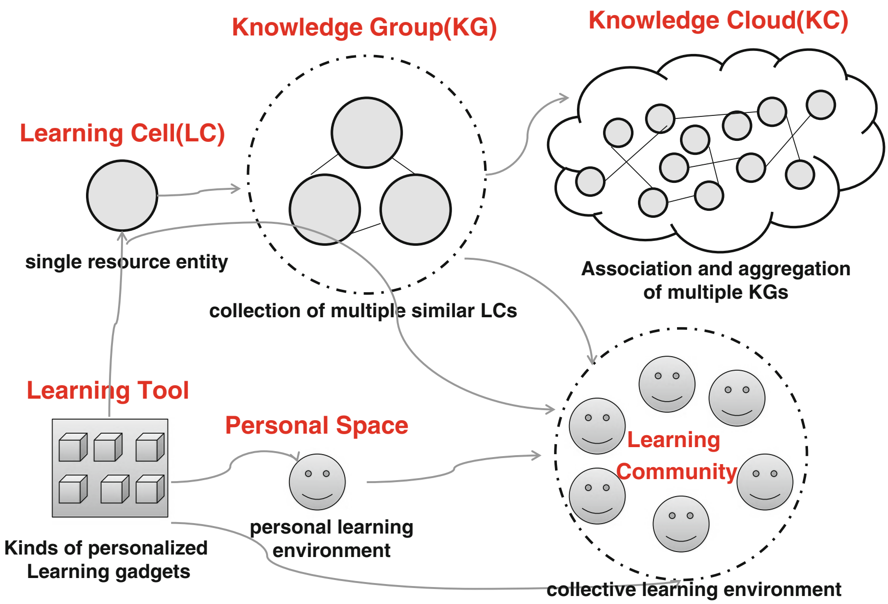

Fig. 8.9 Functional model of the application layer of the learning cell runtime environment

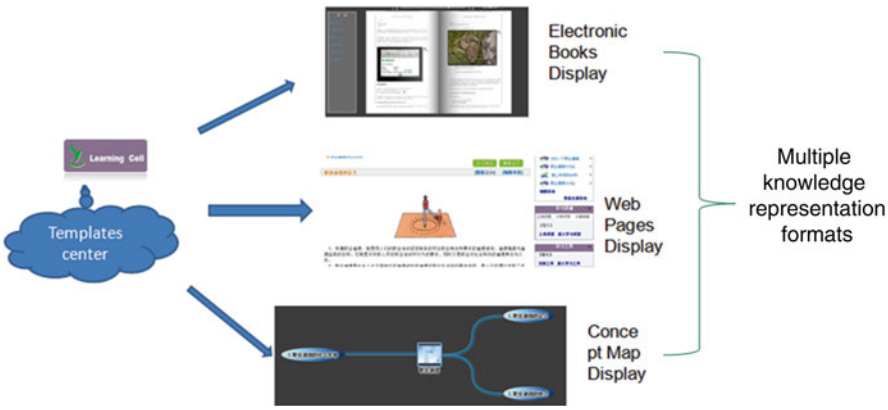

Fig. 8.10 Multiple formats of learning cells

The KG function assembles all of the knowledge groups in the environment. Each knowledge group consists of learning cells on related subjects. For example, a course can be a knowledge group, and each lesson or knowledge point in the course can be a learning cell. When users access the knowledge group, they can find all of the learning cells related to the course.

The KC function aggregates multiple knowledge groups. Different knowledge groups are connected via semantic relationships. In a knowledge cloud, users can easily find all of the knowledge groups related to their subject.

The LT function assembles all of the personalized learning gadgets. In LT, users can preview or save gadgets as well as upload gadgets. All gadgets conforming to Open Social standards can be integrated into LT. These gadgets can be used by learning cells, knowledge groups, personal spaces, and learning communities. For example, some gadgets, such as translating gadgets, can be integrated into the learning content during the content creation or editing process to enhance the learning efficiency.

The LCM function assembles all of the learning communities in the environment. A learning cell is a collective learning environment (CLE) in which community members communicate, collaborate, or share with each other. Community members can publish a notice, initiate a discussion, share interesting resources, and initiate learning activities. Learning communities are related to LC, KG, and LT, and related learning cells, knowledge groups, and knowledge tools can be introduced into learning communities. In addition to learning communities, all users have their own personalized learning environment.

PS is the personal learning environment (PLE) of each user, which contains functions for personal resource management, friend management, schedule management, gadget management, and personalized learning recommendations. In personal space, users can post basic personal information, manage (create, collaborate, and subscribe) interesting learning cells and knowledge groups, and select recommended learning resources.

Features of LCS

Compared with the general online learning system, LCS has six features, as follows:

1. LCS uses ontology technology based on the semantic web to organize various learning resources in the platform. In addition to using the static metadata defined in the IEEE LOM specification, such as title, language, description, keywords, and so forth, LCS also uses an extensible subject knowledge ontology model to represent the intrinsic logic relation between different learning cells.
2. Learning resources in LCS are not fixed, but open toward continual generation and evolution. LCS allows users to collaboratively edit learning content, using the wisdom of the crowd to promote the growth of the learning resources.
3. LCS has an android client developed based on the above model of resources by Gao and colleagues (2012). This mobile app can run on smartphones, tablets, and other mobile devices.
4. Learning resources in LCS involve learning content, activities, as well as social cognitive networks formed through learner interaction with these resources. Beyond general social networks interconnecting people, the social cognitive network shows people-knowledge connections constructed in the process of interaction that is essential to the work of learning communities.

5. LCS captures dynamic semantic relationships among the learning resources. Such relationships are established in an automatic way based on standardized semantic relationship between the resources; they are further updated and developed as the users make change to the resource content, description information, etc.
6. LCS records process information about learners' learning based on five categories: learning attitude, learning activities, content interaction, resources and tools used, evaluation, and feedback. According to different learners' different learning goals, evaluators (generally evaluator is the resource creator, as teacher's role) select the appropriate information and set several personalized evaluation schemes in advance.

Application Scenario Analysis

LCS provides technological support for u-learning. It has been particularly tested to support the following five types of usages:

1. Resource co-construction and sharing

LCS supports the co-construction and sharing of resources in line with the Web 2.0 concept. Any registered user can participate in the co-creation of resources. In schools, teachers and students can create online courses together. With additions and changes of learning resources and information automatically saved, LCS will generate standard courses in conformity with the SCORM standard. Teachers can also collaborate to build the school-base resource center, co-designing teaching plans to address a focal curriculum topic, co-accumulating teaching materials, and integrating these into a whole teaching plan. In corporate training contexts, the human resources department can use LCS to capitalize on the collective wisdom of the staff, to encourage employees to participate in the development of training resources, to realize "training by doing" and "learning by doing," with the collective input of the staffs contributing to building useful training resources for their enterprise.

2. Knowledge management

LCS can also be used to achieve personal and organizational knowledge management. Users can construct their personal knowledge base in LCS, upload their own knowledge resources into a personal knowledge space for centralized management and maintenance. Meanwhile they can share knowledge with friends and engage in ongoing dialogues and interactions. Through this process of participation and interaction, they will establish and perfect personal knowledge networks and social networks. The organization can create different knowledge groups and encourage members to create LCs based on their valuable experience of problem solving and share them within the organization to promote the transformation of tacit knowledge and explicit knowledge and, eventually, to improve the overall organization performance. As an example of using LCS for knowledge management, our "Kuayueshi" (basic education research project) project team and LC project team at Beijing Normal University are using LCS to do project-based knowledge management.

3. Organizational learning

In addition to its rich resources, LCS also provides a library of learning activities and tools. In LCS, organization can attract members to actively participate in learning by designing rich activities and tap into one another's wisdom to promote networking, collaboration, and communication. In addition, members also can upload and share tools closely related to organizational learning and work. When organization members have a problem, they can solve problems through timely communication with the help of special learning tools. The learning activities module in LCS has the function of the online assessment. Teachers can create test questions and design assessments; students can understand gaps in their own knowledge structure by self-testing. Enterprise training department can use the online assessment function to evaluate employees' knowledge and promote the staff's online learning.

4. Regional network-based teaching study

Regional network-based study is an important way to improve teaching quality and promote teachers' professional development. Teachers can share teaching experience with each other through LCS. Research staffs can set research topics and invite teachers of related subjects as collaborators in order to seek breakthroughs of teaching through collective power. They can also build different learning communities for different subjects, encourage the same subject teachers sharing teaching resources, and exchange knowledge and experience online. There are currently ten schools with more than fifty primary school teachers involved in the "Kuayueshi" project (basic education research project) who are using LCS to do regional network-based study in Anhui province of China.

5. College-level online education

Different from the traditional LMS, such as BB, Moodle, Sakai, 4A, etc., LCS has more Web2.0 features besides resource management, discussing and communication, activity design, and other teaching support functions, with more focuses on the construction of knowledge networks and social networks. These features can support online teaching in higher education. Currently, young instructors from the Faculty of Education at Beijing Normal University have started to deploy LCS to conduct network teaching, including the undergraduate course "The design and development of multimedia and network teaching resources" and the doctoral program "The new development of education technology."

Conclusion
Existing schemes focus on learning resource sharing in closed environments. They ignore the sustainable development and evolution of learning resources, the dynamic and generative connections between learning resources, and the dynamic learner-teacher relationship built upon learning resources. The proposed learning cell extends beyond learning objects. It is characterized by an evolving development, cognitive network connections, semantic-based aggregation, self-tracing nature, and micromation features. Learning cell could better support the needs of ubiquitous learning and collective construction to share learning resources. Learning cell is designed to enable future seamless learning space supported by pervasive computing technology, and it will be the keystone in the realization of u-learning.

Our research team has successfully developed a prototype system, learning cell system, and implemented the basic ideas of learning cell. A usability testing was conducted using an SUS tool developed by John Brooke (Brooke 1996). The questionnaires were published using a professional investigation platform (http://www.sojump.com/). Among the 50 users participating in this testing, 68 % felt confident using LCS, 26 % felt neutral, and 6 % felt unconfident and were not willing to use the system. Generally speaking, most users had positive attitudes toward LCS. Further investigations indicated that unconfident users felt that LCS was too complicated. In the future, we will simplify LCS operations and further investigate LCS applications.

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Chapter 9
Supporting Seamless Learning Using Ubiquitous Learning Log System

Hiroaki Ogata, Noriko Uosaki, Mengmeng Li, Bin Hou, and Kousuke Mouri

Abstract This chapter describes a learning log system named SCROLL (System for Capturing and Reminding of Learning Log), which helps users to share and remind ubiquitous learning experiences. It is expected to powerfully assist the implementation of seamless learning. It proposes that seamless learning can be classified into seven types according to the mobile connectivity, and an empirical study in the context of English vocabulary learning at the university level is introduced. The results show that the test group registered fewer words, but learned more words than the control group, and that the linking in-class and outside-class function showed statistically significant effectiveness when excluding two exceptional cases. The participants predominantly used mobile devices during outside-class learning. Therefore, mobile connectivity is, undoubtedly, contributing to the realization of seamless learning in the sense of linking in-class and outside-class learning.

Introduction

In 1994, the American College Personnel Association used the term "seamless learning," stressing the importance of linking the students' in-class and out-of-class experiences to create seamless learning and academic success (cited by Wong and Looi 2011). "Seamless learning" at any level of school can be realized under the circumstance such as CSUL (Computer Supported Ubiquitous Learning) or context-aware ubiquitous learning (u-learning).

CSUL or context-aware u-learning is defined as a technology-enhanced learning environment supported by ubiquitous computing such as mobile devices, RFID

H. Ogata (✉) • K. Mouri
Kyushu University, Fukuoka, Japan
e-mail: ogata@artsci.kyushu-u.ac.jp

N. Uosaki
Osaka University, Suita, Japan

M. Li • B. Hou
Tokushima University, Tokushima, Japan

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tags, and wireless sensor networks (Ogata and Yano 2004). CSUL augments learning in the real world by presenting information on personal mobile devices through the Internet and surrounding environment like physical objects and sensors. Those CSUL applications are intended to be used all the time. This is one of the advantages of CSUL called permanency. It is also the most fundamental element in seamless learning environment. Permanency means that learners never lose their work unless it is intentionally disconnected. Consequently all the learning processes can be recorded seamlessly and sequentially. However, little attention has been paid to this aspect despite that much attention has been paid to other features such as accessibility, immediacy, and interactivity of the Internet, physical environment, and other learners.

The fundamental issues of CSUL are:

1. How to record and share learning experiences that happen at anytime and anyplace.
2. How to retrieve and reuse them in future learning.

To tackle those issues, LORAMS (Linking of RFID and Movie System) (Ogata et al. 2007) was proposed. There are two kinds of users in this system. One is a provider who records his/her experiences into videos. The other is a user who has some problems and is able to retrieve the videos. The system automatically links between physical objects and the corresponding objects in a video and allows sharing them among users. By scanning RFID tags, LORAMS shows the user the video segments that include the scanned objects. Although this system is useful in certain environments, it is not easy to be applied in practice at any place at the moment. Therefore, we started a more practical research called "ubiquitous learning log (ULL)" project in order to store intentionally what we have learned as ubiquitous learning log objects (ULLOs) and consequently reuse them.

We defined ubiquitous learning log object (ULLO) as a digital record of what a learner has learned in daily life using ubiquitous technologies and proposed a model called LORE to show the learning processes in the perspective of the learner's activity. In this paper, we propose a system called SCROLL (System for Capturing and Reminding of Learning Log) that helps learners log their learning experiences with photos, audios, videos, location, QR-code, RFID tag, and sensor data and share ULLOs with others. Also, learners can receive personalized quizzes and answers for their question (Ogata et al. 2011). This system is implemented both on the web and Android smartphone platforms. With the help of built-in GPS and camera on smartphone, learners can navigate and be aware of past ULLOs by augmented reality view.

The rest of this chapter includes related works on life-logs and seamless learning in sections "Related works" and "SCROLL" describes the system called SCROLL, and section "Link rate" describes the SCROLL evaluation conducted under full-seamless condition in the context of English vocabulary learning at the university level. Section "Empirical study with SCROLL" gives conclusions with our future work for the development of seamless mobile environment.

Related Works

Life-Log

Life-log is a notion that can be traced back at least 60 years ago (Bush 1945). The idea is to capture everything that ever happened to us, to record every event we have experienced, and to save every bit of information we have ever touched. For example, SenseCam (Hodges et al. 2006) is a sensor-augmented wearable stills camera; it is proposed to capture a log of the wearer's day by recording a series of images and capturing a log of sensor data. MyLifeBits (Gemmell et al. 2006) stores scanned material (e.g., articles and books) as well as digital data (e.g., emails, web pages, phone calls, and digital photos taken by SenseCam). The Ubiquitous Memory system (Kawamura et al. 2007) is a life-log system using a video and RFID tags. Also, Evernote (www.evernote.com) is a tool for saving ideas using mobile devices such as Android and iPhone.

People can also use SNS (Social Networking Service) such as Facebook, Foursquare, Twitter, and TwitPic for recording and sharing what happened to their lives. Therefore life-log data, in a broad sense, means any forms of recorded data of people's lives. The most common aim of life-log data is to use it for memory aid. SCROLL, on the other hand, aims to utilize life-log data for the learning process. All of the above mentioned projects never encourage learners to learn things. They just save data and share sometimes. SCROLL can remind learners of what they have learned by giving them quizzes and navigate them to the site where the learning objects are nearby learners.

Seamless Learning

The recent progress of mobile and wireless technologies offers us a new learning environment, namely, "seamless learning," and it has been gaining quite a few researchers' attention as a new learning environment (Seow et al. 2009; Boticki and So 2010; Chen et al. 2010; Hsieh et al. 2010; Ye and Hung 2010). What is the difference between seamless learning and m- and u-learning? M- and u-learning focus more on technology and are identified by technology. That is, m-learning is a way of learning using mobile technology. U-learning is a way of learning using ubiquitous technology. "Seamless learning" is, however, one of the pedagogical methods and employs not only mobile and ubiquitous technology but also fixed desktop computers in order to implement seamless learning. In fact according to Chan et al. (2006), "seamless learning" is used to describe the situations where students can learn whenever they want to in a variety of scenarios and that they can switch from one scenario to another easily and quickly using one device or more per student ("one-to-one") as a mediator. The most active domain is language learning and so is our first target domain. In this chapter, by seamless learning, we mean learning which occurs with smooth and seamless transitions between in-class and outside-class learning. Especially we aim to entwine knowledge learned in-class and outside-class. Our goal is seamless learning in terms of knowledge as well as locational seamlessness.

Seamless Rate

How seamlessly we can conduct classes, which we call "*seamless rate*," depends on mobile and fixed PC connectivity. Figure 9.1 shows the correlation between mobile connectivity and seamless rate. The higher the mobile connectivity we afford, the higher the seamless rate we attain for our learning environment. "Mobile" in Fig. 9.1 means a learning environment where a one-to-one-based Internet-connected mobile device such as smartphone, tablet, and PDA is available. "Fixed" in Fig. 9.1 means a learning environment where a one-to-one-based Internet-connected fixed computer is available.

Table 9.1 lists the types of seamless learning available according to mobile/fixed connectivity or seamless rate. There are seven types of mobile seamless learning: (1) full-seamless learning, (2) semi-seamless learning, (3) in-class only non-seamless mobile learning, (4) in-class only non-seamless mobile learning, (5) outside-class only non-seamless mobile learning, (6) in-class only non-seamless fixed learning, and (7) outside-class only non-seamless fixed learning. Further details are described in Uosaki et al. (2013).

When mobile is available for both in-class and outside-class, learning can be fully seamless; thus, we call it "full seamless." We regard in-class and mobile-less condition with fixed computer available for both in and out as "full seamless." It is because this situation (in-class and mobile-less) is not a serious problem to realize seamless environment from a practitioner's perspective because students are likely to sit at the desk and do not move often during class. However, if teachers want students to move around during class, then it is difficult to keep seamlessness.

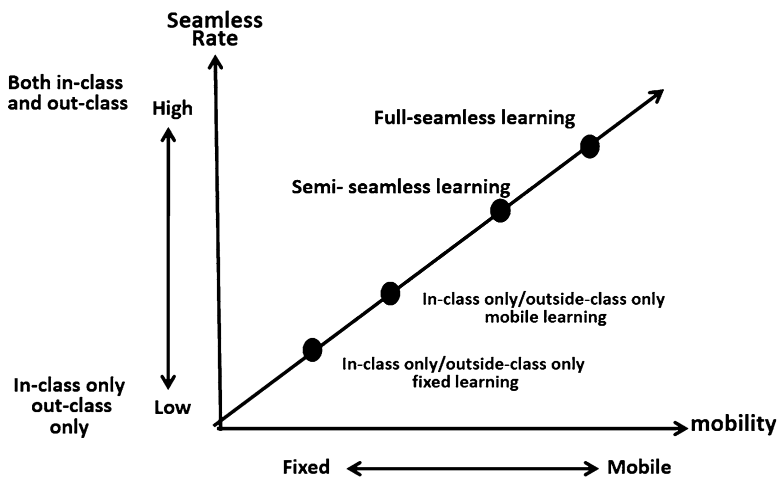


Fig. 9.1 Correlation between seamless rate and mobility

Table 9.1 Type of learning available according to the seamless rate

Seamless rate	In-class		Outside-class		
	Mobile	*Fixed*	*Mobile*	*Fixed*	Type of Learning
High	✔	✔	✔	✔	Full seamless learning
↑	✔	✔	✔		
	✔		✔	✔	
		✔	✔	✔	
	✔		✔		
	✔	✔		✔	Semi-seamless learning
↓		✔		✔	
	✔			✔	
		✔	✔		
	✔	✔			In-class only non-seamless mobile learning
	✔				
			✔	✔	Outside-class only non-seamless mobile learning
			✔		
Low		✔			In-class only non-seamless fixed learning
				✔	Outside-class only non-seamless fixed learning
					Computer-less learning

Therefore, its seamless rate depends on what kind of class the teachers want to run. When fixed computers are available for both in- and outside-classes, we call it "semi-seamless" because even though mobility gets lower, still in and outside learning can be connected through fixed devices.

Linking Method

Since our first target domain is language learning, we needed to consider what is important in the process of language learning and found out that it is most essential to link from one context to another. *The linking method* is based on the concept that the context is important in language learning. We learn words from contexts (Nagy et al. 1985; Krashen 1989; Sun and Dong 2004). The whole (contexts) precedes the part (words) in language acquisition (Engel 1978). "The whole (contexts) precedes the part (words)" means that when children learn their first language, they first grasp the whole situations where the words are used. It has long been pointed out that the second language learning has a similar learning process to the first language acquisition (Dulay and Burt 1973). We need to take word contexts into consideration when we teach/learn vocabulary.

Here is an example why the context is important in learning vocabulary. For many Japanese learners of English, it is difficult to grasp the meaning of "subject to" unless they encounter this phrase repeatedly in different contexts as below:

- All visitors and packages are *subject to* electronic scan.
- This Agreement shall be *subject to* the laws of Japan.
- The terms of your account are *subject to* change.

It is important to link contexts because, according to Nation (1990), 5–16 exposures are necessary to fully acquire a word. Therefore just one appearance of the word in the textbook is far from enough to acquire that word, even though it is intended to be a target word. The reappearance of a word reinforces the form-meaning connection in the learner's mental lexicon (Hulstijn et al. 1996). The more effectively one context is linked to another, the more effectively we can gain our vocabulary. Thus, for the purpose of effective vocabulary learning, we have introduced *linking method* by which we mean that when a learner learns a new word and uploads it to the system, the system informs him/her of other contexts where that word appears.

In fact, learning is not limited to in-class learning. There are various kinds of opportunities of learning vocabulary wherever we are and whatever we are doing. We learn words while watching DVD at home and reading books on the train or at cafe. But this kind of learning usually happens haphazardly and is not related to one another at all. Therefore, we aimed to develop the system which enables linking any kind of learning, either in-class learning or outside-class one.

The significance of our system is that it connects a word in one context to another when uploading the word. The word they learn outside-class and upload to the system is connected to not only the one in the textbook but also the one uploaded by other learners (cf. 3.4). The system supplies other contexts to show how the same word is used in other contexts. By *linking method,* that is, by linking one context to another, it is expected that the system will facilitate learners to build up their vocabulary.

SCROLL

Design

The primary aim of SCROLL is to aid users to capture the learning logs they have learned, review and reflect their old learning logs, reuse the knowledge when in need, be reminded at the right time at the right place, and recommend others' learning logs properly. These functions are expected to powerfully assist the implementation of seamless learning.

Figure 9.2 shows the learning processes in the perspective of the learner's activity model called LORE (Log-Organize-Recall-Evaluate).

1. Log what the learner has learned: When a learner faces a problem in daily life, he/she may learn some knowledge by him-/herself or ask others for help in terms of questions. The system records what he/she learned during this process as a ULLO. The SenseCam technology supports users' recording (Hou et al. 2013).
2. Organize ULL: When the learner tries to add a ULLO, the system compares it with other ULLOs, categorizes it, and shows the similar ULLOs if they exist. By matching similar objects, the knowledge structure can be regulated and organized.
3. Recall ULL: The learner may forget what he/she has learned before. Rehearsal and practice in the same context or others in idle moments can help the learner

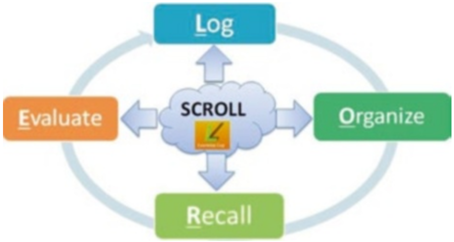


Fig. 9.2 LORE model in SCROLL

to recall past ULLOs and to shift them from short-term memory to a long-term one. Therefore, the system assigns some quizzes and reminds the learner of his/her past ULLOs (Li et al. 2013).

4. Evaluate: It is important to recognize what and how the learner has learned by analyzing the past ULL so that the learner can improve what and how to learn in the future. Therefore, the system refines and adapts the organization of the ULLOs based on the learner's evaluation and reflection. All the above learning processes can be supported by SCROLL.

Interface

Mobile Interface

To simplify the process of capturing the learning experience, the system provides a well-defined form to illustrate a learning log. It includes four basic elements, which are the time when the learning occurred (when); the knowledge (what); the sequence recorded in texts, photos, audios, or videos that the learning should comply (how); and the location where the learning happened (where). Besides, the logs can be organized by tag and category. Figure 9.3(1) is the interface of adding a new learning log, and Fig. 9.3(2) is an example of a learning log.

One of the significant functions in our system is the location-based context awareness. The location-based learning log is regarded as the knowledge that can be recalled by the location or place as a retrieval cue. Its purpose is to remind learners of what they have learned when they come to the place where the learning happened. According to the theory of encoding specificity, the place where we learned can be encoded as a retrieval cue initially, and it is effective to activate a stored memory (Tulving and Thomson 1973). For example, if we learned the Japanese names of vegetables in a supermarket, when we enter the supermarket next time, some of what we have learned may come into our mind again.

SCROLL also provides some other functions such as LL navigator and Time map. LL navigator is a function providing the learner with a live direct view of the physical real-world environment augmented by a real-time contextual awareness of the surrounding learning logs (Fig. 9.3(4)). Additionally, when a learning log is

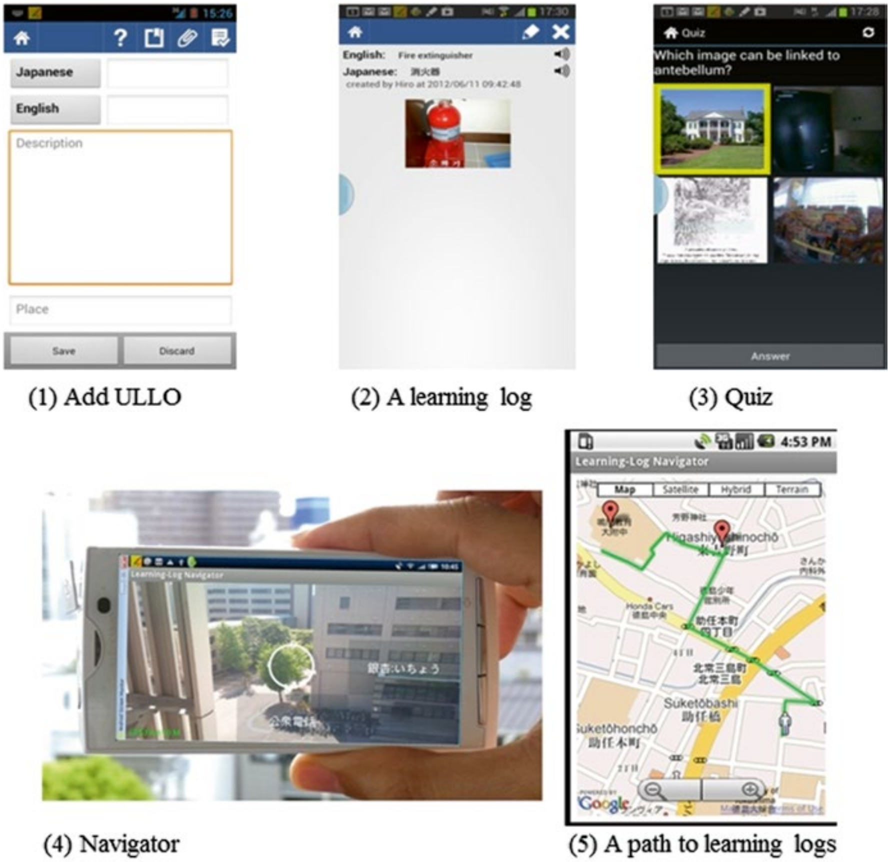


Fig. 9.3 SCROLL interfaces of Android mobile phone

selected in the LL navigator, the system will show a path (route) for the learner to reach to the selected objects from his/her current location (Fig. 9.3(5)) (Mouri et al. 2012). The Time map function means that the user can scroll the timeline above, and then the map below will display the learning logs recorded during the learners' selected period. It is designed to help the learners to reflect what they have learned. A more detailed description on the functions of the SCROLL system can be found in Ogata et al. (2011).

Web Interface

Figure 9.4 (left) shows an example of registered ULLOs. If the user presses the "Relog" button, this object will then be included in his/her "my log." The Q&A (question and answer) and comments about this ULLO are also listed in the window.

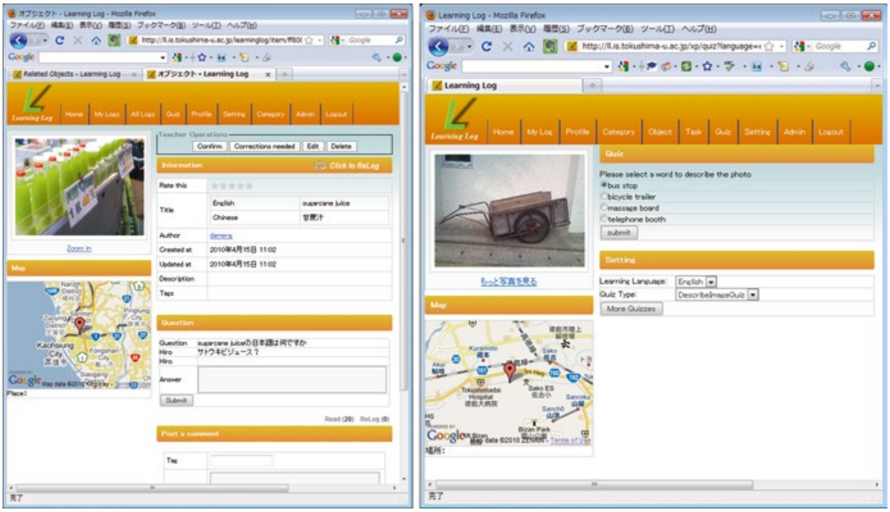


Fig. 9.4 An example of ULLO (*left*) and quiz (*right*)

Figure 9.4 (right) shows a multiple-choice quiz, which is automatically generated by the system. If the user presses the answer button, the right answer will appear. If the user thinks this is not a good quiz, he/she presses the pass button. Then, the quiz will not appear again.

Textbook Database

In order to make learning seamless in terms of entwining in-class learning with the outside-class one, it is necessary to link in-class and outside-class learning. Therefore, textbook database adding function and linking functions were developed as described in sections "Textbook database", "Linking in-class learning with outside-class learning", and "Linking one learning log with another".

Textbook data can be uploaded to the system anytime anywhere as far as they are PDF files and can be used as teaching/learning materials. Students can read textbook files anytime anywhere for previewing and reviewing with either mobile devices or PCs.

In the electronic textbook, registered words are classified by color. The words which were registered by the learner himself are shown in crimson color. As for the words which were registered by other learners, the shown color differs according to the number of the learners who registered that word. It is shown by the gradation of blue color. When the number of the learners who registered a certain word was more than 4, that word appears in medium blue. When the number was 2–3, the word is shown in royal blue, while when the number was only one, the word is shown in dark turquoise.

Linking In-Class Learning with Outside-Class Learning

Figure 9.5 shows how in-class vocabulary learning and outside-class vocabulary learning are linked. When a student registers "credit" during his/her outside-class learning (1), the system shows him/her the textbook line where it appears as well as the chapter title and line number (2), If he/she clicks the line (3), it jumps to the textbook page (4) so that he/she will be able to read full contexts. The system aims to let him/her know that he/she has already learned it in-class or he/she is supposed to learn it in the future. That way he/she can review or preview the word learned or to be learned in the textbook. This linking function is significant because, as a general concept, people are likely to forget what they have learned. In fact, forgetting learned vocabulary is a serious problem during learning English vocabulary (Chen and Chung 2008). Even though the student felt "credit" was new to him/her, the system lets him/her know that he/she has learned it before in the textbook.

Linking One Learning Log with Another

A student's learning log can be linked to that of others in a textbook page. In the electronic textbook, registered words are hyperlinked. As shown in Fig. 9.6, when a student clicks "medium" (1), a side bar pops up and the names of the students who

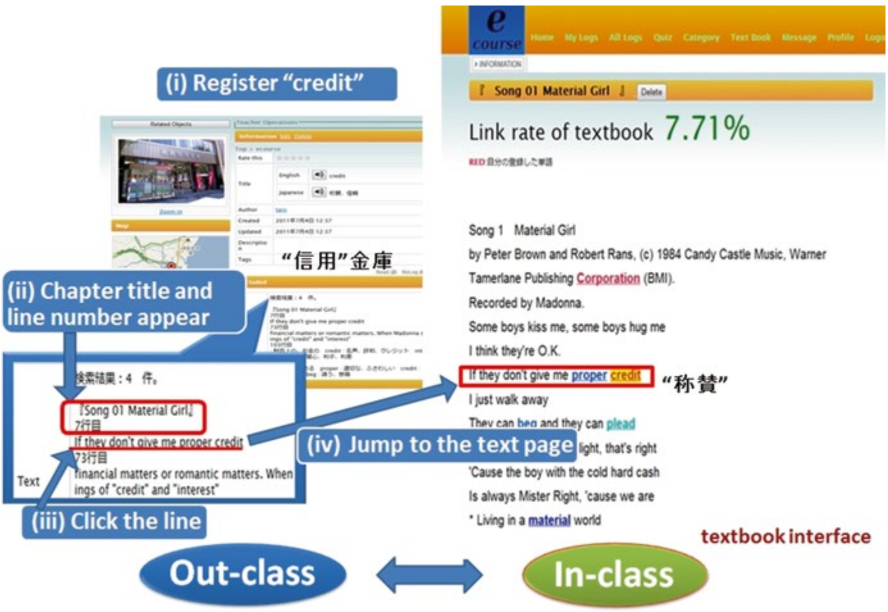


Fig. 9.5 Link between in-class learning and outside-class learning

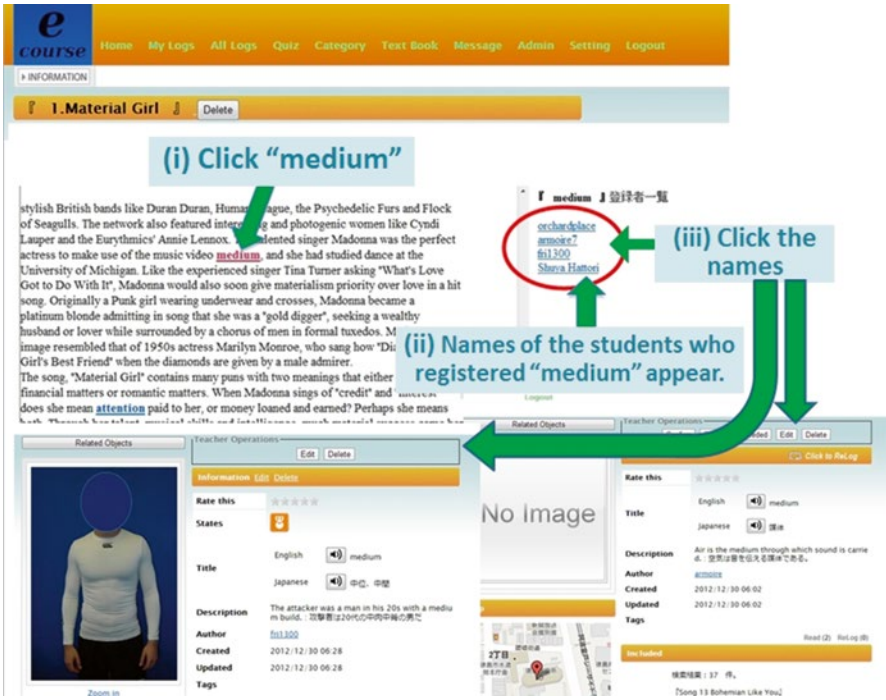


Fig. 9.6 Link between one's learning logs and other classmates' learning logs in a textbook page

registered them appear (2). Then when the student clicks his/her classmates' nickname "fri1300" or "armoire," it jumps to their pages of "medium" (3).

With the help from the system, students can be aware of what they have learned before, and what other students are learning, and the teacher can grasp what the students are learning outside-class and incorporate students' unplanned self-learning into classroom activities so that close link between in-class and outside-class learning will be realized.

Link Rate

Our emphasis in "seamless learning" as mentioned in section "Seamless learning" is entwining knowledge learned in-class and outside-class. We measured the *link rate* in order to examine whether the linking function of our system contributed to students' vocabulary learning. As mentioned in section "Linking method", our basic idea is that we learn words by encountering them in one context to another. The linking function of our system helps learners to learn words by showing them in other contexts. The higher link rate means the more frequently learners encountered a certain word in different contexts. The system measures a *link rate* and shows it on the top page of each chapter (Fig. 9.5). The *link rate* is calculated as follows:

$$link\ rate = \frac{(number \text{ of registered words})}{(number \text{ of words in the chapter}) - (\text{number of words lerned during the 7th grade} + \alpha)}$$

The above equation shows the rate of overlapped vocabulary learned in in-class and outside-class learning. “The number of registered words” in the equation means the number of words that one learner registered to the system and that appeared in the chapter. “The number of words learned during the 7th grade” in the equation means the number of words learned during the 7th grade which appeared in the chapter. The number of words learned during the 7th grade is 398 in total. The 7th grade is the first year of learning English in Japan. So they are very easy, fundamental words. “α” in the equation means words which are easy but not among the 7th grade vocabulary, which appeared in the chapter. We excluded these words because college undergraduates are most unlikely to register such words. “Words which are easy but not among 7th grade vocabulary” described as “α” in the equation were judged by an experienced English teacher.

Based on our *linking method* described in section “Linking method”, our hypothesis is that the larger the *link rate* one learner attains, the more effectively he/she can gain new vocabulary. The *link rate* is shown in each uploaded file or chapter by chapter in the case of the textbook. By grasping the *link rate*, the learners are able to know how much vocabulary learned outside-class is overlapped with the textbook vocabulary (learned in-class) and so does the teacher.

Empirical Study with SCROLL

In this section, one real classroom implementation of SCROLL is introduced. Among the various functions equipped in SCROLL, we focused on its linking function in order to examine how SCROLL could contribute to the implementation of a successful seamless learning by linking in-class vocabulary learning and the outside-class one. The evaluation was conducted under full-seamless condition to examine if SCROLL contributes to more effective vocabulary learning than the conventional method (cf. Uosaki et al. 2012).

Method

The study group consisted of 38 Japanese university freshmen of Basic English class, who were divided into two groups with equal English proficiency according to their pretest results. The evaluation lasted from June 14 to July 12, 2011. The students took two types of pretests. The experimental group learned vocabulary using SROLL with Galaxy Tab SC-01C as well as home PCs and classroom PCs. The control group learned vocabulary in a conventional way memorizing words by reading, writing, and making their own vocabulary books. This is a common practice when students learn vocabulary, a traditional way of learning vocabulary in Japan. They uploaded their vocabulary books made by spreadsheet software at least once a week so that the instructor could grasp what they have learned. Both groups were assigned to do some outside-class learning (mainly reading). They were informed that their commitment to vocabulary learning directly reflected their grades. At the conclusion of the phase, the subjects underwent two kinds of posttests, the same ones as the pretests. Further data was collected from the participants by means of questionnaires and the log data stored in the server.

Results

1. *Comparison Between Uploaded Words to the System and Words Listed on Spreadsheets.*

As for Group A, a total of 2,162 learning logs (mean = 120/person) were uploaded to the system, while the total number of words listed on spreadsheets by Group B was 3,584 (mean = 179/person). The number of listed words of Group B was larger than that of uploaded words of Group A. Registering words to the system takes more time than just listing words on spreadsheets. One of the authors conducted an experiment on how long it took to list words on spreadsheets and register words to the system. The average time taken to list words on spreadsheets was 25.7 s, while it took 42.3 s on average to register a word to the system. This easy operation of spreadsheets apparently contributed to this result (Table 9.2). However, Group A members could see and relog (as in "retweet" in twitter) the uploaded objects by others, so they did not necessarily have to upload objects by themselves to learn words.

2. *Test (1) Results*

Pretest and Posttest (1) are web-based vocabulary tests called V-check test (http://www.wordengine.jp/). Test takers take it for about 10 min, and the system predicts each test taker's command of the English vocabulary. The test contents differ every time they take the test. Vocabulary in Test (1) was not related to the vocabulary in the textbook.

Pre- and Posttest (1) results of Group A and Group B are presented in Table 9.3. Group A shows a larger improvement than Group B. Statistically significant difference was detected between Group A's Pretest and Posttest (1) results ($t = 3.52$, $p = 0.00063$), while there was no statistically significant difference as for Group B results.

Table 9.2 The number of words uploaded/listed

	The number of words uploaded/listed
A (test group)	2,162 (120/each)
B (control group)	3,584 (179/each)

Table 9.3 Pretest and Posttest (1) results (full mark 20,000)

	Pretest (1)	Posttest (1)		
	mean (SD)	mean (SD)	*t*	Effect size (*d*)[1]
A (test group)	5,082	7,221	3.52*	1.21 (large)
	(1647.2)	(1876.7)		
B (control group)	5,459	6,757	1.75	0.57 (medium)
	(2053.4)	(2454.3)		

$*p = 0.00063$
V-check test (http://www.wordengine.jp/)

Table 9.4 Pretest and Posttest (2) results

	Pretest (2)	Posttest (2)		
	mean (SD)	mean (SD)	*t*	Effect size (*d*)
A (test group)	25.62 (10.49)	60.54 (18.29)	6.67*	2.36 (large)
B (control group)	31.98 (10.10)	64.39 (15.12)	7.70**	2.53 (large)

(textbook vocabulary test)
$*p = 5.03 \times 10^{-8}$
$F = 2.13 < F\alpha$
$**p = 1.669 \times 10^{-9}$

3. *Test (2) Results*

Pretest and Posttest (2) were made from vocabularies from the textbook. The Pretest and Posttest (2) results of Group A and Group B are presented in Table 9.4.

Both groups show dramatic improvement. There was a statistically significant difference between Pretest and Posttest (2) results for both groups as summarized in Table 9.4 (Group A: $t = 6.77$, $p = 5.03 \times 10^{-8}$ $df = 33$, $d = 2.36$/Group B: $t = 7.70$, $p = 1.669 \times 10^{-8}$ $df = 37$, $d = 2.53$). Since the content of Test (2) was predictable, they could prepare for it. On the contrary, Test (1) content is totally unpredictable. This difference directly reflected the test results.

4. *Entwining In-Class Learning with Outside-Class Learning*

One key issue in this chapter is how we can entwine in-class vocabulary learning with the outside-class one. We developed the system to link words learned outside-class and words learned in-class. In order to show how outside-class vocabulary learning is linked with the in-class one, the system measures a *link rate* chapter by chapter (cf. section "Link rate").

We examined the correlation between the link rate and the Pretest and Posttest (2) improvement (Fig. 9.7). The coefficient of correlation between the link rate and the Pretest and Posttest (2) difference was 0.334. No statistically significant correlation was detected as the following formula indicates:

$$r^2 = 0.1116 < 0.21\{4/(n+2)\}$$

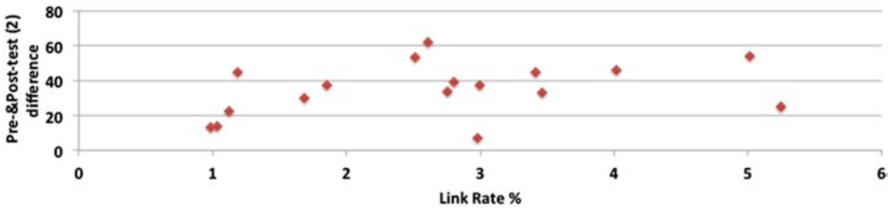
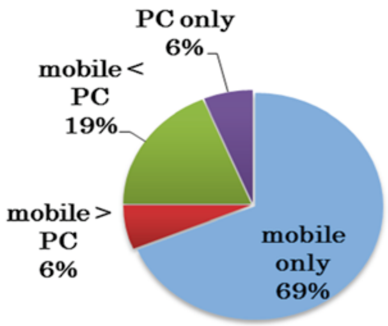


Fig. 9.7 Correlation between link rate and Pretest and Posttest (2) difference

Fig. 9.8 Devices students used more often for outside-class learning



5. *Which Is More Fitting for Vocabulary Learning, PC or Mobile?*

Group A students used mobile device more often than PC in their outside-class learning according to the result of a questionnaire by which they were asked which device they used more often in outside-class learning, PC or mobile. The questionnaire was a quadruple choice style: (1) mobile only, (2) mobile > PC, (3) mobile < PC, and (4) PC only. The result reads: (1) mobile only 11, (2) mobile > PC 1, (3) mobile < PC 3, and (4) PC only 1 (Fig. 9.8). Therefore it can safely be said that the mobility of mobile devices, which enabled anywhere-anytime-based vocabulary learning, contributed to their outside-class vocabulary learning. This result endorsed that mobile devices are fitting tools for vocabulary learning.

6. *Quizzes*

Totally 4,318 quizzes were done by Group A (mean = 239.8, SD = 169.87). There was a statistically significant correlation between learning time and the number of times of doing quizzes as the following formula indicates:

$$r = 0.51 \quad r^2 = 0.26 > 0.2\{4/(n+2)\}$$

But no statistically significant correlation was detected between the number of times of doing quizzes and Pretest and Posttest (2) difference as the following formula indicates:

$$r = 0.009 \quad r^2 = 0.000081 < 0.2\{4/(n+2)\}$$

Discussion

1. *Which Is More Effective, the System or Vocabulary Books in Terms of Vocabulary Learning Method?*

The test group showed a larger improvement for both tests than the control group as given in Table 9.5 and shown in Fig. 9.9 though statistically significant difference was not detected. As for Test (1), though the test group scored less at pretest, they outscored the control group at posttest. Since the content of Test (1) is totally unpredictable, they could not prepare for it. On the other hand, Test (2) is a vocabulary test of 70 words from the textbook. Since the subjects were informed that posttest results would reflect their grades, it seemed they prepared well for the posttest. We believe the adequate preparation made both groups perform almost equally at Posttest (2).

As mentioned earlier, the number of textbook words on spreadsheets for Group B (126 words each) was 159 % larger than the number of the system-uploaded textbook words of Group A (79 words each) (cf. Table 9.2). Nevertheless, the increased difference of Pretest and Posttest (2) (the textbook vocabulary test) for Group A was three points larger than that of Group B (cf. Table 9.5). It means that Group A uploaded fewer words, but learned more words than Group B. In this sense, the system was more effective and supportive than the spreadsheet vocabulary book though *t*-test did not show it was statistically significant.

Although statistically significant difference was not detected between the two groups' pre- and posttests increase, the quantitative and qualitative data suggest certain tendencies. For example, the questionnaire conducted after the evaluation revealed that the majority of the test group students (16 out of 18) enjoyed quizzes outside the class:

> It was convenient to answer quizzes using mobile device when I had a small amount of free time.

Using devices seemed to motivate them to learn vocabulary:

Table 9.5 Increase difference between Pretest and Posttest (1) and (2) results

	Group A (test group)	Group B (control group)	*t*
Pre-to-Posttest (1) increase mean (SD)	2,193 (1,585.59)	1,337 (2,366.13)	1.22*
Pre-to-Posttest (2) increase mean (SD)	35.1 (14.82)	32.5 (14.05)	0.52**

$^*p = 0.114$
$^{**}p = 0.303$

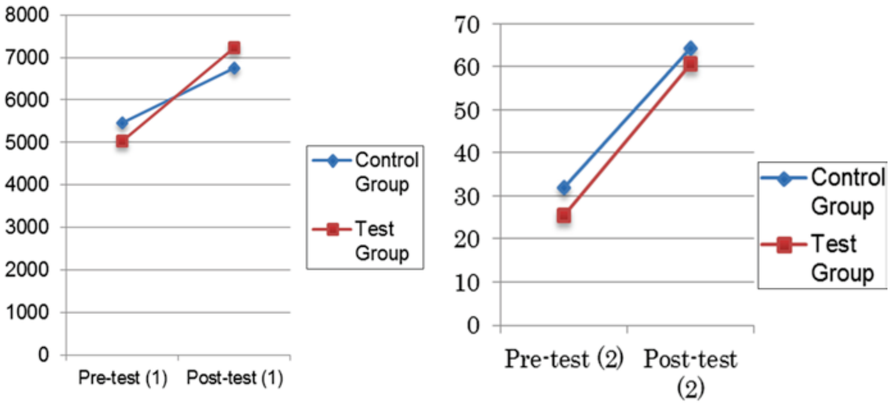


Fig. 9.9 Pretest and Posttest (1) results (*left*) and Pretest and Posttest (2) results (*right*)

When I registered words to the system, I felt like I wanted to learn more words.

On the other hand, some students felt it was troublesome to use devices:

It was troublesome to charge the device every day.

Some students wanted to learn vocabulary using paper:

I wanted to print out a vocabulary list which I registered to the system.

2. *Link Rate Reconsidered*

Table 9.6 shows Group A students' Pretest and Posttest (2) differences and link rates (mean = 2.68, SD = 1.26). Pretest and Posttest (2) difference of Student #11 was extraordinary small (+7.3), compared with the average increase (mean = 35.06), though his/her link rate was high (2.98) and Student #17 had the similar tendency. These exceptional cases influenced the whole data since the number of the sample was rather small. Therefore we excluded these two cases and reexamined the correlation. Then the coefficient of correlation went up to 0.64. It showed statistically significant correlation between the link rate and Pretest and Posttest (2) difference:

$$r^2 = 0.41 > 0.24\{4/(n+2)\}$$

Since this correlation was acquired after excluding the two exceptional cases, we made a close investigation into these two students' cases. It was found that outside-class learning time of Student #11 was extraordinary short, the shortest of all (30 min). It was most unlikely that the student of the shortest learning time had a high link rate. By investigating his/her link rate on each chapter, it was found that only the Chap. 12 link rate was exceptionally high (5.43), which pushed up his/her average link rate of the whole 4 chapters as high as 2.98. The average link rate of Chap. 12 of the whole Group A was 3.52. In order to figure out why only the Chap. 12 link rate was high, we further examined his/her Chap. 12 linked words.

Table 9.6 Pretest and Posttest (2) difference and link rate

Student	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Pre- and Posttest (2) difference	13.1	14	22.4	44.8	29.6	37.3	53.3	61.9	33.7	38.9	7.3	37.1	44.8	33.2	46.1	53.7	24.8
Average link rate from Chaps. 8, 9, 11, and 12	0.99	1.04	1.12	1.19	1.68	1.86	2.51	2.61	2.76	2.8	2.98	2.99	3.42	3.46	4.02	5.01	5.25

One linked word ("freight") appeared 5 times in the chapter, and two of the linked words ("pun," "rowdy") appeared 4 times, which could be the cause of enhancing his/her link rate.

Conclusions and Future Works

This chapter described seamless learning featuring a ubiquitous learning log system called SCROLL, the system which we have developed in order to enhance sharing and reusing past learning experiences. The evaluation to examine the effectiveness of SCROLL was also depicted.

The results are as follows: (1) The test group showed a larger improvement for both tests than the control group. The test group uploaded fewer words, but learned more words than the control group. In this aspect, SCROLL was more effective and supportive than conventional vocabulary learning. Statistically significant difference, however, was not detected. (2) As for the relation between the link rate and the Pretest and Posttest (2) difference, the correlation was statistically significant, when we excluded two exceptional cases. Therefore, it can safely be said that SCROLL could be a powerful tool to assist the implementation of a successful seamless learning by linking outside-class learning and in-class learning. For instructors or any kind of parties who are interested in seamless learning, we set practice-based guidelines to implement a seamless learning environment using SCROLL (Uosaki et al. 2013).

The subjects predominantly used mobile devices during outside-class learning, which endorsed what is generally believed that mobile devices are more fitting tools for vocabulary learning than PCs.

As our future work, in order to improve our present quiz system, we are now working on a new quiz system by introducing manpower to create quizzes. Besides, by utilizing sensor technology, customized learning recommendation system is under development so that the system can give learners recommendations actively and aggressively at an appropriate timing and an appropriate place. The system does not just wait for a learner to upload a new word, but it autonomously lets a learner learn new word by recommending him/her according to their situation. It is expected that smartphones will be equipped with more sophisticated sensors in the future, and the device will know learners better to capture their learning habits more accurately. Since we usually have only one teacher per class and what the teacher can do is limited, peer-to-peer collaboration is necessary for successful seamless learning. Therefore as another future work, we are planning to add an appealing social network type of function, in order to promote the students' interaction and outside-class learning.

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Chapter 10
Situated Learning Theory and Geo-collaboration for Seamless Learning

Gustavo Zurita and Nelson Baloian

Abstract Situated learning stresses the importance of the context in which learning takes place. It has been therefore frequently associated with informal learning or learning outside the classroom. Therefore, this theory offers an excellent basis for developing applications supporting collaborative learning activities implementing seamless learning. In this chapter, we present and analyze two applications designed with the principles of situated learning, which implement learning activities taking place inside and outside the classroom without interruptions of either learning methodology or technical platforms. The first one supports the learning of models for wireless signal propagations. It starts with a classroom activity for learning the theoretical models, and then a field trip is used to measure actual signal strengths and compare them with the data generated by the models. The second one is a learning system and a methodology based on the use of patterns. Students learn about patterns by finding instances of them in the field or by recognizing new patterns unknown to them so far. The teacher proposes tasks to the students consisting of finding instances of patterns or discovering new ones along a path or inside a predefined area on a map. Both systems support the features of seamless learning across various scenarios in and outside the classroom, due to the encompassing formal and informal learning, personalized and social learning, physical and virtual worlds, across time and location, and ubiquitous knowledge access by context-aware in real learning scenarios.

G. Zurita (✉)
Department of Information systems and Management, Economics and Business Faculty, University de Chile, Diagonal Paraguay 257, RM, Santiago de Chile, Chile
e-mail: gzurita@fen.uchile.cl

N. Baloian
Department of Computer Sciences, Universidad de Chile, Blanco Encalada 2010, RM, Santiago, Chile
e-mail: nbaloian@dcc.uchile.cl

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Introduction

Situated learning is a general theory of knowledge acquisition that emphasizes the importance of the activity, the context, and the culture in which learning occurs (Lave and Wenger 1991). Social interaction is another critical component of situated learning; learners become involved in a "community of practice" which embodies certain beliefs and behaviors to be acquired. Educational technologists have been applying the notion of situated learning over the last two decades, in particular promoting learning activities that focus on problem-solving skills (Kurti et al. 2007; Miura et al. 2010; Vanderbilt 1993) and the use of GPS data to pinpoint geographical locations (Clough 2010). In this work, we also consider the geographical location as an important context component which enriches the information the students are dealing with. In fact, in many scenarios the knowledge is inherently attached to the location where it is applied. One example may be a particular geological formation being studied or an architectural pattern which may shed some light about the development of a city revealing the data and architectural trends which prevailed when certain buildings where constructed.

The notion of "cognitive apprenticeship" (Brown et al. 1989) is also closely related to "situated learning" as: "Cognitive apprenticeship supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity. Learning, both in and outside school advances through collaborative social interaction and the social construction of knowledge."

Now, the integration of one-to-one computer-to-learner models of technology enhanced by wireless mobile computing and position technologies provides new ways to integrate indoor and outdoor learning experiences. The notion of "seamless learning" (Wong and Looi 2011) has been proposed to define these new learning situations that are marked by a continuity of learning experiences across different learning contexts. Students, individually or in groups, carry out learning activities whenever they want in a variety of situations and that they switch from one scenario to another easily and quickly. In these learning situations, learners are able to examine the physical world by capturing sensor and geo-positional data and conducting scientific inquiries and analyses in new ways that incorporate many of the important characteristics suggested by situated learning.

In this chapter, we describe our current research efforts that include the design of a learning environment that integrates mobile applications and geo-collaboration tools in order to support seamless learning based on the Situated Learning theory. Learning activities in these settings take place in and outside the classroom and encourage students to collect data in the field in order to find, relate, and document patterns of any nature. An important element of the collected data is the geographical location where instances of the pattern being learned are located.

Situated and Seamless Learning Activities Supported by Geo-localization

Situated Learning and Geo-localization

Some interesting applications supporting learning activities guided by situated learning making use of geo-referenced data over maps and mobile devices have been developed in the past years (see Table 10.1 for examples). Few of them rely upon geo-localization features that characterized Geographic Information Systems (GIS). A GIS offers several functionalities, such as associating by geo-reference information of different nature to a specific geographic location using visually represented maps; recording the history of routes; making notes on real geographic points of reference, places, or zones; determining routes; comparing different notes made in different locations; following certain locations; etc. These different functionalities and information layers certainly may introduce an added value to situated learning applications supported by geo-localization, as they allow to make connections between places, content, learning activities, and learners.

Therefore, collaborative activities can be introduced in situated learning scenarios and also to providing the seamless learning features by letting participants collaborate geo-reference information, as well as solving tasks in particular locations taking advantages of the affordances of mobile technologies. Students may collaboratively work at the same time and in the same place, at the same time and in different places, at different times in the same place, or at different times in different places. These types of collaborative activities have not been widely explored yet in situated learning settings since most of the research efforts have only focused on one or another modality. Moreover, few efforts consider the benefits of other learning modalities like personalized and social learning, encompassing physical and digital worlds, ubiquitous knowledge access, combining use of multiple device types, knowledge synthesis, or learning with patterns (Wong and Looi 2011).

Lave and Wenger (1990) suggest that learning is better off when knowledge is presented in an authentic context, i.e., settings and applications that would normally involve that knowledge. They also claim that learning requires social interaction and collaboration. Brown et al. (1989) list a set of procedures that are characteristic to cognitive apprenticeship in a situated learning context: starting with a task embedded in a familiar activity which shows the students the legitimacy of their implicit knowledge and its availability as scaffolding in apparently unfamiliar tasks, allowing students to generate their own solution paths which helps make them conscious creative members of the problem-solving context, and helping students to acquire some of the culture's values. In order to make the ideas guiding situated learning, it is necessary to identify its critical aspects in order to enable it to translate into teaching and learning activities that could be applied inside and outside the classroom (Brown et al. 1989). In response to this challenge, Herrington and Oliver (2000)

Table 10.1 Characterization of representative research projects using geo-collaborative situated learning applications. R1 to R9 rows correspond to the requirements of situated learning applications describe above

Reference	Mattila and Fordell (2005)	Ogata et al. (2006)	Kurti et al. (2007)	Wijers et al. (2008)	Bahadur (2009)	Miura et al. (2010)	Edge et al. (2011)
Place	Outside/inside the classroom.	Outside/inside the classroom.	Outside/inside the classroom	Outside the classroom	Outside the classroom	Outside the classroom	Outside the Classroom
Objective	Learning in a mobile scenario by sharing observations	To learn Japanese in real-life situations	Enhance content of the curricula. Enriching the field experience	Game learning to analyze and learn math problems	Game learning through participation and problem solving	Easily record and sharing of knowledge using maps, sketches	To learn Mandarin in real situations
Users	Primary and secondary school students	20–30-year-old users	4th and 5th grade students	12–14-year-old students	Secondary students	Sixth graders students	23–42 years old users
Technology	Mobile phones with cameras	PDA with GPS, Bluetooth. Wi-Fi, and smart board	Nokia 6630 with GPRS connection and HP iPAQ 6515 with GPS	Mobile phone with a GPS receiver	Laptops with GPS receiver and Google maps	Tablet PC, a USB camera, and GPS receiver	iPhone with GPS
Collaborative mode	Same time, different places between students and teacher using a voice channel	Same time, same place, and different places among users and teacher	Same time, place among students, different place and time between students and teacher	Same time, same place	Same time, same place, and different places among students	Students interact and share with different roles. Same time, same place	Not specified
R1	√	√	√		√	√	√
R2	√	√	√	√	√	√	√
R3	√						
R4	√					√	
R5	√	√	√	√	√	√	
R6	√	√	√	√		√	√
R7	√	√	√	√	√	√	√
R8	√	√	√				
R9	√	√					

suggest a practical framework for designing situated learning activities including the following situated learning requirements:

R1. Provide authentic contexts reflecting the way knowledge is used in real life.
R2. Provide authentic activities.
R3. Provide access to expert performances and the modeling of processes.
R4. Provide multiple roles and perspectives.
R5. Support collaborative construction of knowledge.
R6. Promote reflection to enable abstractions to be formed.
R7. Promote articulation to enable tacit knowledge to be made explicit.
R8. Provide coaching and scaffolding by the teacher at critical times.
R9. Provide for authentic assessment of learning within the tasks.

Recently, a few situated learning applications that rely on geo-collaboration have been tested, and they are described below. Table 10.1 presents a selection of related research efforts in this field ranging from 2005 until today, which include the usage of mobile devices and geo-localization over maps.

Moop (Mattila and Fordell 2005) is a learning environment supported by mobile phones, through which learners analyze their thoughts and make observations. It has been designed for primary school children and has the following tools: a control for a camera, a video camera and a voice recorder. When a GPS-locator is connected, the location information will follow observations automatically. A location-bound task course is created with the help of a GPS locator, and a user can easily proceed on course to reach the set goals. Planning the route with the Moop's map view allows for a variety of learning situations and study plans. With the teacher application it is possible to plan the route directly live on course in the nature and in the observation place.

LOCH (Ogata et al 2006) describes a computer-supported ubiquitous learning environment for seamsless language learning. It was conceived to assist overseas students to learn Japanese while involved in real-life situations. Students can make use of their PDAs for writing down annotations, recording questions, taking pictures, and reporting back to the teacher. At anytime, the teacher is monitoring the position of the students and can establish communication with them, either through instant messaging or IP phone, both preinstalled on the PDA.

In AMULETS (Kurti et al. 2007), children use a mobile application with GPS to learn about "tree morphology" and "the history of the city square through centuries." The system challenges the students to identify different types of objects and conducting some tasks including recording still images and video describing how they solved the tasks they were assigned. In order to solve these problems, students are required to collaborate using a number of tools including instant text messaging between smartphones and computers.

MobileMath (Wijers et al. 2008) is designed to investigate how a modern, social type of game can contribute to students' engagement in seamless math learning. It is played on a mobile phone with a GPS receiver. Teams compete on the playing field by gaining points by covering as much area as possible. They do this by constructing squares, rectangles or parallelograms by physically walking to and clicking on each vertex (point). During the game, in real time the locations of all teams and all finished quadrilaterals are visible on each mobile phone.

The treasure hunt game (Bahadur and Braek 2009) has been developed as a case study to help analyzing a specific domain and designing a generic and flexible platform to support situated collaborative learning. Students go around the city and learn how to participate in several social/group activities.

In SketchMap (Miura et al. 2010), children carry a PDA and create a map using a stylus pen by drawing streets and placing icons such as hospitals or municipal offices. Using a USB camera attached to the tablet PC, children can capture an image or a video which is shown as an icon. The icon can be dragged from the palette to anywhere on the map. The system supports reflection by allowing the children to replay their map creation processes. Annotations on the maps allow children to add new information or experiences, related to what they have discovered after their outdoor activities. The children can collaboratively share information and knowledge about neighboring areas in the vicinity of their school.

In Micromandarin (Edge et al. 2011), a database of English-Chinese translations associated with their context of use was created. This application supports key functions: studying language based on where you are, using language you have learned based on where you are, and browsing all language you have seen through the application.

Based on the information shown in Table 10.1, we can conclude that from the requirements stated by (Herrington and Oliver 2000), the less frequently considered are the access to expert performances and the modeling of processes (R3), the coaching and scaffolding by the teacher at critical times (R8), and the authentic assessment of learning within the tasks (R9).

In the next sections, we present two applications based on the principles of situated learning supporting seamless learning across various scenarios in and outside the classroom.

Seamless Learning in Situated Learning

We consider that mobile geo-collaboration is an interesting option for designing computer-supported learning applications implementing seamless learning complying with the principles proposed by Wong and Looi (2011) in the following way:

SL1. *Bridging formal and informal learning*. The teacher may complement the theoretical educational content seen in the classroom (formal learning) with activities outside the classroom (informal learning). These activities may involve geo-location of data referring to the educational content by marking them on a map, carrying an historical record, and comparing the points, places, or geographical zones which students explore by themselves or visit by instruction of the teacher.

SL2. *Bridging personalized and social learning*. Students can perform learning activities individually, in small groups, by ad hoc networked group forming, and collaboratively; all these modalities may be configurable and combinable. For example, an activity might start by performing individual work and then evolve to a collaborative, face-to-face one. Moreover, the teacher may offer feedback synchronously or asynchronously, while students are engaged geo-localizing information in the field or afterwards.

SL3. *Bridging across time, across locations*. Students can move across various geographical places anytime in order to perform the tasks proposed by the teacher. They can also work collaboratively synchronously or asynchronously. The teacher may provide feedback synchronously or asynchronously as well. By making use of the current services available in the cloud (e.g., Google Maps, Google Street View), students may work in the field or virtually visiting a certain place.

SL4. *Encompassing physical and digital worlds*. Theatrical knowledge acquired in the classroom by means of "digital worlds" (simulation, models) can be checked and/or used in "physical and real worlds," for example, by searching concrete instances explained by the models.

SL5. *Ubiquitous knowledge access*. This means students can pull or push information from the Internet when learning is taking place in a specific geographic location. In this way, the contextualized information (to and from the students) can serve as evidence to support partially formed ideas and clarify misunderstandings, to trigger comparison with previously stored data, and to support an inquiry process or dialogue in situ. The contextual information pulling (buildings, parks, museums, etc.) can be provided by the place where the students are developing their activities (by the use of the GPS functionality of the mobile devices).

SL6. *Encompassing physical and digital worlds*. It is possible to combine digital and physical worlds with ambient environments that capture real-world information of users, devices, and locations (geographical information systems) and represent it in a format that is usable in the digital realm.

SL7. *Combined use of multiple device types*. An alternative to cope with the problem of the various existing mobile platforms that are incompatible (Android, IOS, BlackBerry OS, Symbian OS, Windows Mobile) is the use of open standards for developing applications capable of running on a browser. HTML5 has features like offline storage or the ability to handle data even when the app is no longer connected to the internet, geo-location, or the ability to detect and work with the location of the user as well as excellent rich media support, providing easy to implement audio and video elements. We propose the use of HTML5 to implement the functionalities, which we are mentioning here.

SL8. *Bridging multiple learning tasks*. This feature is about seamless and perhaps rapid switches between multiple learning tasks on the move (e.g., during field trips), mediated by the device. The tasks that we propose strike a balance between the restricting in situ activities (data collection and measurement, quick brainstorming or Internet search, brief note taking and geo-referencing data and information) to more sophisticated data analysis and knowledge co-construction tasks (i.e., deep meaning making) for the follow-up learning community after the field trips. The embodiment of such inquiry tasks in mobile seamless learning flows could serve as a means to nurture the twenty-first century skills and competencies.

SL9. *Bridging knowledge synthesis*. The ultimate aim of embracing seamless learning is arguably the synthesis of knowledge and the acquiring of the skills to perform the synthesis. We propose to implement functionalities to acquiring data in different contexts, locations, domains and forms and recording, organizing, processing and reflecting upon the knowledge. This will be mediated by him/her own mobile device that serves as a learning hub, thereby making connections and perhaps identifying discrepancies between pieces of knowledge and ultimately knowledge construction.

In the next two sections of this chapter, we introduce two applications designed with the principles of situated learning, which implement learning activities taking place inside and outside the classroom. The first one (section "Geo-collaborative application for learning wireless signal propagation") supports the learning of models for wireless signal propagations. The second one (section "Geo-collaborative application for "learning with patterns"") is a learning system and a methodology based on the use of patterns. Students learn about patterns by finding instances of them in the field or by recognizing new patterns unknown to them so far. Both systems support the features of seamless learning across various scenarios in and outside the classroom. They highly relay on the use of geo-located data to carry on the learning activity. They address the three requirements (R3, R8, and R9), which are more neglected by the similar applications considered in the literature review.

Geo-collaborative Application for Learning Wireless Signal Propagation

Many scholars agree that teaching and learning wireless communication is a challenging issue mainly because it is difficult for students to translate the theoretical models that are commonly used in this area to explain the propagation of the signal into explicit, practical knowledge (Etter 1994; Junqi et al. 2009). This knowledge is essential order to be able to plan wireless networks settings, which is a fundamental activity for this area. From a pedagogical perspective, situated learning offers an interesting framework to support the translation of abstract, theoretical knowledge into concrete skills by applying knowledge in realistic settings and carrying out authentic activities (Denk et al. 2007).

In wireless network planning, engineers must determine the location of a set of transmitters (antennas) and their characteristics, like transmission power, frequency, direction, etc., in order to cover an area using the minimum of resources (Yijia 1996). In order to do this, engineers normally use software, which simulates using mathematical models the propagation of the signal emitted by a transmitter. There exist various models that simulate the propagation under various landscape conditions (urban areas, suburban areas, mountainous areas, flat countryside areas, etc.) (Iskander and Yun 2002; Santos et al. 2005; Hata 1980). Choosing the right model for each situation is not an easy task because some scenarios may combine various landscape types at the same time. Therefore, planning the network requires performing real measurements at various locations in order to check if the applied model predicted the propagation correctly. Otherwise it will be necessary to correct the assumptions. It is important that engineering students understand the difficulty in choosing the right model and that the chosen model may not apply for the whole area which they are considering for simulating the signal propagation.

Situated learning recommends that students perform these modeling activities in a real environment with the help of an expert and having the opportunity to reflect about the learning experience. Collaboration is also considered by the situated learning to be an important aspect that should be present in this process.

The design and deployment of large-scale wireless networks consisting of various antennas providing a certain area with service, using minimum resources constitutes a real engineering activity actually performed by professionals of this area. This process has three stages: planning, implementation, and evaluation.

The *planning* stage is performed using cartographic information about the area, which should be covered with the signal emitted from the set of antennas, and using a signal coverage simulation tool. This activity consists of locating a set of antennas and simulating the area covered by them using available simulation software. Normally, software of this kind implements various electromagnetic signal propagation models and allows the user to choose which one to utilize in each case. The *implementation* stage consists on building the network of antennas based on the planning stage. Finally, the *evaluation* stage consists on measuring with real instruments that is the actual coverage of the signal by taking samples of the signal strength in various geographical strategic points. The information obtained from the measurements is gathered and contrasted with the data obtained by the simulation during the planning stage in order to make the necessary adjustments to the network for obtaining the desired results.

Starting from the described activity taken from the real life, a learning activity was designed based on the Situated Learning theory, which mainly consists in carrying on the evaluation stage. For this, we defined two roles: planner and measurer. For each role a specialized tool was developed in order to support their activities.

The learning activity envisages two sessions: the first one is the theoretical session where students learn in a classroom setting the various existing models for simulating the signal propagation. During the second session a practical workshop is performed which starts by defining working groups consisting of four students each. Two of them take the role planners and the other two the role of measurers. The tasks to be performed are also divided in two stages: the first one is the *input of data* stage and the second one the *evaluation* stage.

During the *input of data* stage *planners* will make a signal coverage analysis for a set of existing real antennas using a signal coverage simulation tool (see Fig. 10.1) and a collaboration tool (see Fig. 10.3). Both tools have two different interfaces implemented, one designed to be used on a desktop PC and the other to be used on mobile

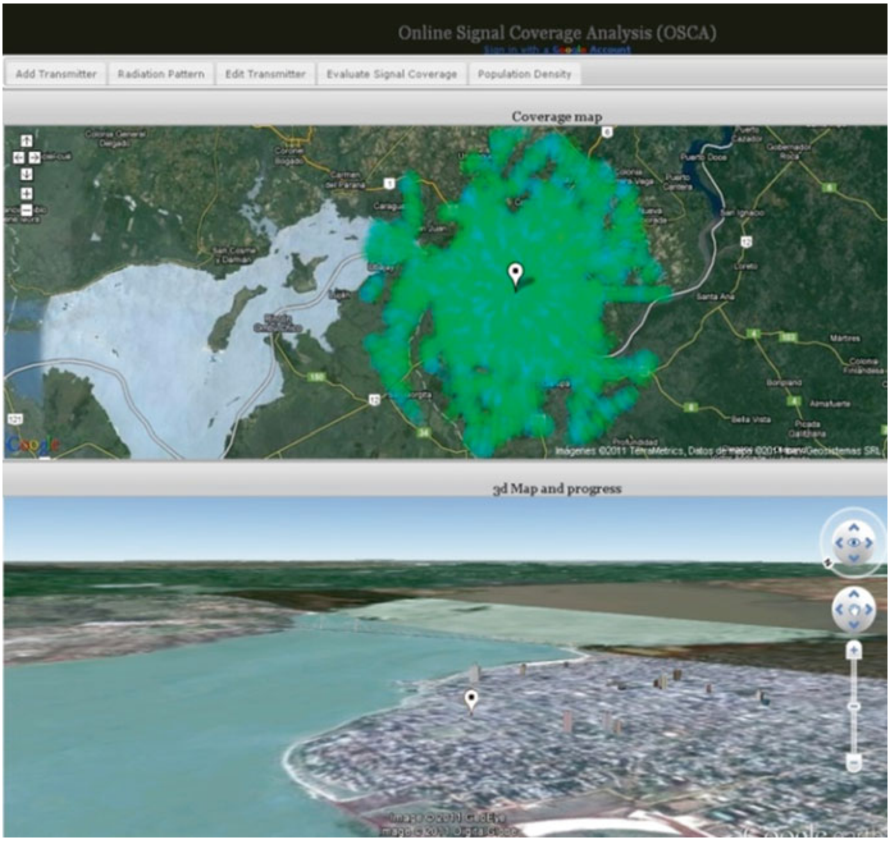

Fig. 10.1 Coverage analysis tool on desktop browser with the 2D (*up*) and 3D (*bottom*) views. The *white* marker on both views represent the location of the antenna. The *light green* area of the 2D view corresponds to the area covered with signal according to the simulation model

devices (see Fig. 10.2). Students get the necessary information about the antennas in order to perform the simulation like the geographical location, height, strength, radiation pattern, etc. This information is used to feed the signal coverage analysis software, which actually performs the simulation after students choose the propagation model they consider is the most adequate given the cartographic information provided by Google Earth. Once the simulation is performed and simulated data about the signal strength for the whole area is obtained, students receive a set of coordinates of various geographical points, which they have to input into the collaboration tool along with the data about the simulated signal strength for each of these points.

During this stage the *measurers* have to go to the places designated by the coordinates, which were given to the *planners*. At those places, *measurers* use professional signal strength tools to obtain the corresponding information of the real signal strength at that location. Then, they input this data using the collaboration tool in order to share it with the rest of the team.

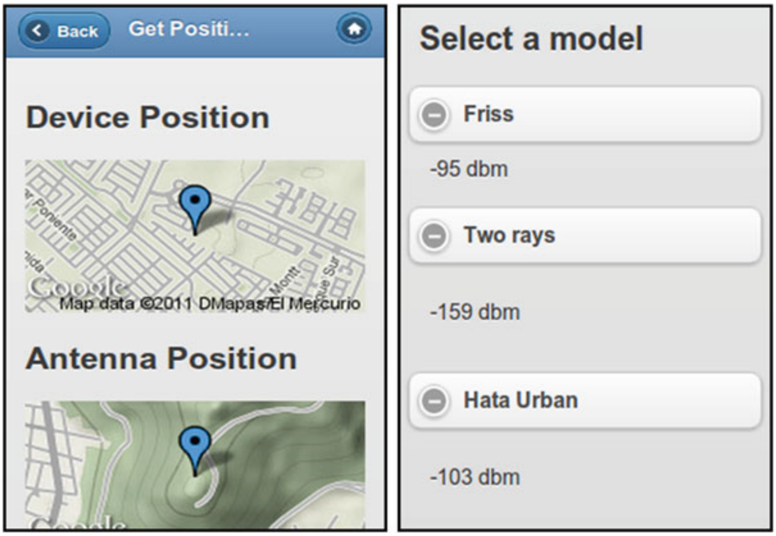

Fig. 10.2 The picture on the *left* shows the upper half of the mobile device's interface. The map on the *top* shows the student's current position according to the device's GPS. The map on the *bottom* shows the antenna's location. On the *right*, the bottom half of the interface shows the signal strength values according to each available model is displayed

During the *evaluation* stage, *planners* and *measurers* work using a collaboration platform we have developed (a detailed description is provided in the next section) in order to find which is the model that better predicts the real measured value of the signal strength by comparing both data: the simulated and the measured. However, students will realize that there is no single model, which predicts the real value for the whole area. The actual learning occurs when students have to justify the reason for this, by checking the different geographic and building scenarios in site. The system allows them to input and browse the simulated and real data in order to compare them and start discussion.

The Software and Hardware

As mentioned in the previous section the software consists of two applications, one for each role. These are the coverage analysis tools for planners and the collaboration tool, which is used in both steps by both roles. The first one was already developed for a previous work reported in (Baloian et al. 2012) for supporting a learning activity for a single learner scenario. The collaboration tool interacts with the coverage analysis tool and was developed in order to enhance the learning experience by including the collaborative learning activities in the way the Situated Learning theory recommends.

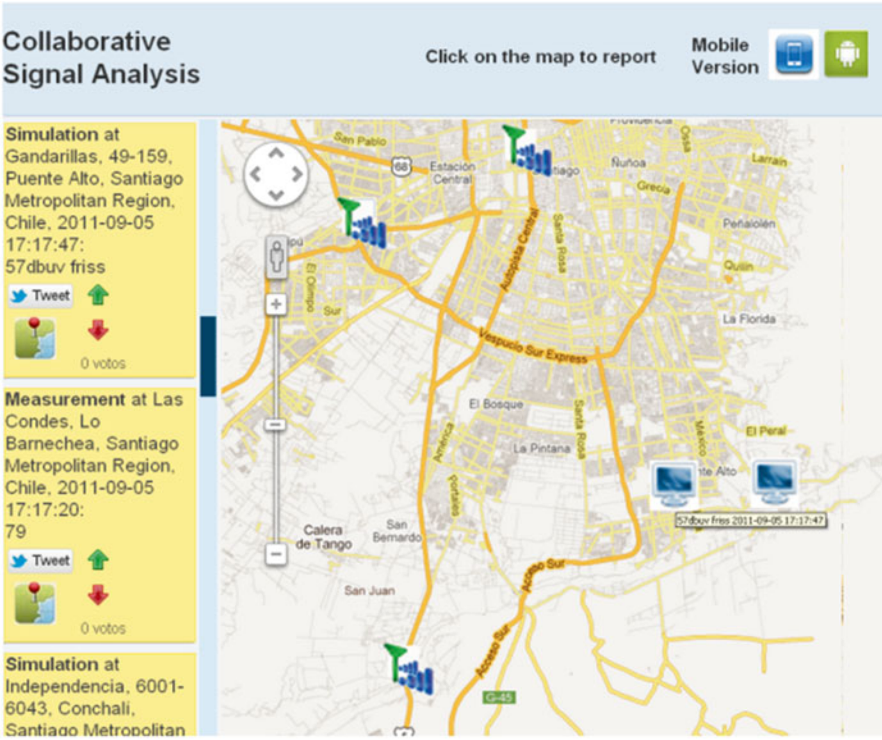

Fig. 10.3 The desktop web browser interface is used to input simulated or measured signal strength values for various locations. For this the user clicks on the map and enters the information. Screen icons indicate a simulated value for that location was inputted; antenna icons indicate a measured value. On the *left* column, detailed information for each data on the map is shown

Coverage Analysis Tool

This tool has two interfaces, one for desktop computers and another for mobile devices. The desktop interface supports the planning activity in the classroom that includes performing simulations and storing the generated data. The mobile interface is designed to provide the simulation data while working on the field.

The desktop interface has four main features:

Add transmitter: The goal of this feature is to provide an easy way to perform the planning step, using a 2- and a 3- dimensional map. The 2D map is used to specify an approximate location of the antenna. This map is synchronized with the 3D view (see Fig. 10.1). After this, the antenna can be set with a double click on the 3D view. Then, the technical specifications of the transmitter can be filled in a pop-up form (not shown in Fig. 10.1), which includes the propagation model to be used in the simulation.

Edit a transmitter: In order to allow students to test different models, the specifications of a transmitter can be edited.

Radiation pattern: Each type of transmitter has a specific radiation pattern, which defines the transmission power on a specific direction. This is an important parameter for simulating the signal strength.

Evaluate the spatial coverage: This function performs the actual simulation by computing the signal strength in the whole area by applying the selected propagation model for that antenna.

The mobile interface allows students to retrieve the simulated signal strength values at the current location according to all available models while students are working on the field. First, the Select antenna function should be performed in order to choose the antenna from the available set according to which the signal strength should be computed. Then the GetPosition button should be pressed in order to let the system retrieve the current position of the student with the mobile device using the GPS of the mobile device. Then the system shows the simulated signal strength emitted from the selected antenna at the device's position according to all available models. Figure 10.2 illustrates the system's interface for the mobile devices. At the right-hand side, the simulated signal strength according to the available models is displayed. At the left-hand side, the mobile device's position (where the student is current standing) and the selected antenna position are shown. By clicking on the button labeled with the model's name, more information about the simulation results is displayed.

The Collaboration Tool

This tool has also two interfaces, one for desktop and another for mobile devices. The desktop interface is used during the planning activity in the classroom, and the mobile is the collaboration tool that is used on the field while students are measuring the signal strengths. The desktop version has two features: report a simulation value and vote for a measurement or simulation. The mobile has three features: report a measurement, and vote for a measurement or simulation.

Report a simulation (available on desktop version only): Students publish the simulated signal strength for a certain location. The goal of this procedure is to have the values available for the evaluation step, in order to allow students to compare this value with the measured one (see Fig. 10.3).

Vote (available on desktop and mobile versions): During the evaluation step students have to choose the most adequate model to predict each measured value of the signal's strength. While planners have better information about the simulation results and the geographical characteristics of the area between the antenna and the device position, measurers have on-site information about the local conditions for a certain point. Both actors can use the voting system to express their preference for one model or the other according to their information.

Report a measurement (on mobile version only): This functionality allows students on the field (measurers) to publish measured values to the rest of the group (other measurers and planners). The measurer first obtains the signal strength with a measuring device. In order to publish this value, the button labeled with Signal should be pressed, then the value should be typed in and the Report button pressed. The system automatically adds the location information using the GPS feature of the mobile device and shows it on a map.

Geo-collaborative Application for "Learning with Patterns"

Patterns play a significant role in learning. Research findings in the field of learning psychology provide some indications that human learning can be explained by the fact that learner discover, register, and later apply patterns (Ewell 1997; Howard et al. 1992; Restle 1970). These cognitive processes "involves actively creating linkages among concepts, skill elements, people, and experiences" (Ewell 1997). For the individual learner, the learning process involves "making meaning' by establishing and re-working patterns, relationships, and connections" (Ewell 1997).

Learning with Patterns

Patterns are recurring models and often are presented as solutions for recurring problems. Natural sciences, mathematics, and arts also work with patterns. The exact use of the term, however, varies from discipline to discipline. The first formalization of pattern description and their compilation into networks of "pattern languages" was proposed by Alexander et al. (1977). A pattern consists of a set of components including the name of the pattern, the description of the problem it solves, the solution to this problem, an example, and the relations it has to other patterns. This approach has been adopted by many disciplines like architecture, software development (Erich et al. 1995), interaction design (Borchers 2000), and pedagogy (The Pedagogical Pattern Project 2013). Although the evidence that patterns play an important role in learning, they have seldom been used to support the development of cognitive and social skills apart from the field mathematics. Here we show how this concept can be further be used to support learning.

Application Description

Based on the information described in the previous paragraph, we have developed a prototype of a system to support geo-collaborative learning activities that include collecting data on the field in order to find evidence of previously known patterns, for example, knowing the patterns of neoclassical architecture found in the city or discovering patterns starting from the evidence found in the field (e.g., studying the

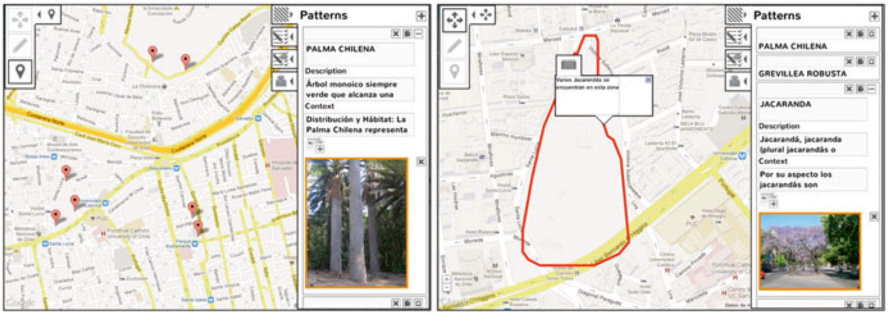

Fig. 10.4 Teacher's view of the system. *Left*: pattern creation of a "Palma Chilena" with a picture of it that is geo-localized in the exact locations where they are found. *Right*: pattern creation of a "Jacaranda," whose picture illustrates an example and also the region where they are found, which is indicated on the map

Fig. 10.5 Teacher's view of the system for the task definitions, which are made by following a path (*left*) and marking specific locations (*right*) in which the students need to work with

reasons of why certain patterns of trees appear more often in city parks). According to the specific scenario described in the next paragraphs, the following functionalities for a system supporting them have been identified:

Creating patterns: To create a pattern means to define its components, describing its elements: name, description, context, etc. For each pattern, these components are annotated over the map by freehand writing (see Fig. 10.4). Additional multimedia objects (pictures, videos, etc.) can be associated to the description of the pattern.

Creating tasks: Teachers can create tasks consisting of instructions to be given to the students, containing the description of activities and their corresponding instructions annotated over the map with a specific path (left of Fig. 10.5) or to randomly explore a pre-defined area within the city in order to find evidence of patterns (right Fig. 10.4) or visit specifically marked places (right of Fig. 10.5). Therefore, the teacher can define a path, an area, or mark points by freehand

Fig. 10.6 Two students' views, with instances of the patterns and tasks provided by their teacher. Each of the three tasks shown in both interfaces belongs to the same team. The third assigned task is highlighted on the *left* and the *right* shows the first. Both interfaces show the task development already done collaboratively

sketching the limits of it onto the map. Consequently, the task for the students will consist of exploring a geographic area by following a path, randomly visiting a concrete area, or specifically visiting marked locations, in order to collect data about the instances of a pattern. Furthermore, the teacher can associate previously defined patterns to the task or create new ones inside the task creation process. Figure 10.2 shows the creation of various tasks and their associations of these to the corresponding pattern(s).

The teacher can create these patterns and tasks during the class, as they are presented to the students before using an electronic board or projecting the screen of a touch-sensitive computer to the whole class.

Assigning tasks to students: In the classroom, and before going to the field activity, students turn on their mobile devices (Tablets or Tablet PCs) running the application. The teacher's application automatically discovers the students' application and displays them on the screen as an icon. By just dragging and dropping the student's icon over the task icon, the task proposition is transmitted to the student's device and shown.

Instantiating patterns: According to the proposed task, students may follow a certain path, explore an area of the city, or go to specific places gathering data to collaboratively create instantiations of the pattern when they find certain elements that they think correspond to the pattern given by the teacher. Instantiations consist of text descriptions, pictures, or sketches of a certain object found which complies with the pattern definition; see Fig. 10.6.

Monitoring students' work: Teachers can monitor the students' work in areas where Internet is available and a client-server communication is possible. The student's application sends the current position at regular time intervals to a server. This information is taken by the teacher's application, which displays the student's position on the map. It is also possible for the teacher to communicate with the students via chat to give more instructions about the task in "real time."

Conclusions

Current developments in mobile computing and wireless networks facilitate and promote the implementation of computer-supported learning systems that can be deployed ubiquitously. The Situated Learning theory can be used as a good frame for designing computer-supported learning activities, which take place in the field. An interesting subset of this kind of learning systems is the set of applications that make intensive use of geo-referenced information, when the knowledge being acquired is strong related to a geographical location. In this work, we are proposing the design of learning activities that incorporate elements of situated learning that are supported by the use of geo-collaboration tools and mobile applications. From our literature review, we can see on the one hand that learning activities using mobile technologies and geo-collaboration have been successfully implemented, and on the other hand, it has been recognized that patterns can play an important role in the learning process. This is mainly due to current developments in mobile computing and wireless networks, which allow the development of computer-supported learning systems that can be deployed ubiquitously. The Situated Learning theory is a good frame for the development of computer-supported learning activities that take place in the field. An interesting subset of this kind of learning systems is the set of applications that make intensive use of geo-referenced information, when the knowledge being acquired is strong related to a geographical location. A key element for these systems is the availability of maps and geographical information in general. This is fortunately nowadays provided as Cloud Services by a number of providers for free.

In section "Situated and seamless learning activities supported by geo-localization", we presented the characteristics of seamless learning. Here, we will analyze how the two developed systems fulfill them. Table 10.2 illustrates how the developed applications comply with the mentioned characteristics, some in a better way than others. An important characteristic of the learning approach proposed in our current efforts is that it starts in the classroom, continues on the field, proceeds then at home or in a computer lab, and ends with a learning session inside the classroom again. This again can create another cycle which is interesting from the point of view that these systems are able to support different learning modes and stages, without disruptions of methodology, interaction paradigm, or data compatibility. In fact, the systems are able to run on different platforms. They have been used on PCs inside the classrooms, where the teacher used an electronic board. Handheld and Tablet PCs have been also used to run these systems. The common aspect on all these platforms is the touch screen and the big difference is the size.

The design of both developed systems considers functionalities which include the requirements of situated learning mentioned in (Herrington and Oliver 2000). Particularly, they consider the three requirements (R3, R8, and

(continued)

Table 10.2 The requirements and the system features fulfilling for both seamless learning applications (SL1 to SL9)

	Application for "Learning with Patterns"	Application for "Wireless Signal Strength Propagation"
SL1	Formal learning takes place in the classroom with the teacher explaining and presenting patterns; informal learning takes place in the field with students finding instances	Formal learning takes place in the classroom with the teacher explaining and presenting various models of signal propagation; informal learning takes place in the field with students measuring actual values and discussing about the validity of each model
SL2	Personal learning occurs when students learn a pattern and social learning when they collaboratively work in the field collecting instances and discuss about them	Personal learning occurs when students learn the models theoretically; social learning occurs when they take the measurements in the field and share and compare their analysis results in order to find the best prediction model
SL3–4	Students learn the theory about patterns in the classroom and then they work in the field gathering data and come back to the classroom to present their findings. All this is done in different times and places	Students learn the theory about models in the classroom and then they work in the field taking measures. Then they discuss about the obtained data synchronously or asynchronously
SL5	Mobile devices allow students to access the information about the patterns anywhere and anytime, which will help them to accomplish their task; they also may receive advice from the teacher during the field trip	With the mobile devices students have access to the simulation data as well as other information they may download from the internet
SL6	Students work with digital maps annotating them in order to represent facts of the real world	Students must compare the results given by the simulated world with the real facts of the measured data
SL7	The technology used to develop the application (HTML5) allows it to be run in a variety of devices	Same as for the other application
SL8	Since the application interface used in the classroom and the one for the working in the field are very similar, the switching between the various tasks is easy	Although applications used in the classroom or laboratory and the one used in the field are not similar, the interaction logic in all of them has been kept coherent in order to facilitate the switching from one task to another
SL9	Students present their findings in the field back in a classroom session where they reflect about the importance and distribution of the pattern instances	Students reflect on results of measurements obtained in the field in order to generalize the acquired knowledge

(continued)

R9) which are more neglected by the similar applications considered in the literature review: (R3) in both cases, the teacher can interact in real time with the students while they work in the field; (R8) because of this, the teacher can offer coaching and scaffolding at critical times; and (R9) the teacher can asses students' work in authentic conditions.

We think that the approach presented in this chapter can be applied to different learning fields, for example, (a) Geology students must perform collaborative activities like field measurements and observations that can be monitored and controlled remotely by a teacher. Students must geo-reference their notes, take pictures, and make recordings at concrete points that will be constructed jointly and/or with their peers; (b) Architecture students may recognize construction styles and design patterns in specific areas of an urban space. Students may also collaboratively survey construction styles or design patterns in a certain zone using geo-referenced notes to understand the changes in the construction development; (c) Social sciences – students of anthropology, psychology, or sociology may conduct field observations for which collaboratively created data and information notes of diverse nature (text, images, video, and sound), associated with its localization, will enrich their observations.

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Chapter 11
Requirements for a Seamless Collaborative and Cooperative MLearning System

Paul Birevu Muyinda, Godfrey Mayende, and Jonathan Kizito

Abstract There is need for mobile learning (mLearning) systems that are capable of spurring seamless collaborative and cooperative learning. Such systems would be instrumental in redefining the way academic and administrative student support services are extended to students who might find themselves situated in different learning spaces and with multiple societal roles. In this chapter, the Mobile Learning Object Deployment and Utilisation Framework (MoLODUF) was used to underpin a study from which requirements necessary for the development of a seamless collaborative and cooperative mLearning system were instantiated. The adduced requirements include the need for communication cost subsidies and putting in place mechanisms for harnessing positive mLearning policy elements. Other requirements relate to human, financial and infrastructural resources for spurring mLearning. The system also requires an authentication protocol to prevent unauthorised use and unsolicited communication. It also requires GSM and GPRS mobile network connectivity so as to embrace low- and high-end mobile phones and mobile and PC interoperability. The system needs to be designed for learners who are located in multiple contexts and with multiple roles. Text and audio media types are ideal for learning objects that are seamlessly interoperable on low- to high-end mobile phones and PCs. The system as well should be cognisant of the need for learning comfort and learning object delivery feedback. These system requirements have been used to develop a prototype seamless collaborative and cooperative mLearning systems using SMS technology.

Background

With the proliferation of mobile devices, users are freed from transacting different processes in tethered environments. In the education sector, learners and their teachers are increasingly using mobile devices for pedagogic services, a learning notion

P.B. Muyinda (✉) • G. Mayende
Department of Open and Distance Learning, Makerere University, Kampala, Uganda
e-mail: mpbirevu@cees.mak.ac.ug

J. Kizito
Department of Computer Science, Makerere University, Kampala, Uganda

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known as mobile learning (mLearning) (de Marcos et al. 2006). Compared with conventional eLearning, mLearning is a relatively new form of technology-enhanced learning. It entails learners learning at anytime in any place using mobile devices (Traxler 2007). It is a form of eLearning which employs wireless, handheld and portable devices to extend and deliver learning to learners (de Marcos et al. 2006). This chapter conceptualises mLearning as any act of using any services rendered by a mobile device to extend learning or learning support. MLearning benefits from the fact that ownership of mobile devices is now more pervasive than tethered communication devices especially in developing countries of Africa (Muyinda et al. 2011). This is making the design and development of mLearning systems a reality.

MLearning systems can enhance academic and administrative support for open, distance and eLearning (ODeL) students in hitherto contact universities (Muyinda et al. 2011). These universities are opening their doors to ODeL provision as a way of providing access to flexible higher education. For instance, in its 2008/2009–2018/2019 Strategic Plan, Makerere University considers ODeL as one of its strategic actions for fulfilling the core function of teaching and learning (Makerere University 2008). By their very characteristics, ODeL students are disparately located; hence they live in multiple contexts. These attributes place a requirement for a seamless ODeL academic and administrative support system. Innovative technology-enhanced student support systems for seamless learning come in handy.

Seamless learning is defined as a learning model which permits learning at anytime and anyplace either in a formal or informal learning space using mobile devices as mediating tools (Chan et al. 2006 cited in Zhang and Looi 2011). The phenomenon of seamless learning connotes the reception of learning experiences ubiquitously (Milrad et al. 2013). In seamless learning, the learning device adapts learning content to the prevailing learning context of the learner (Uden 2007; Toh et al. 2013). In seamless learning therefore, learners receive equal learning experiences irrespective of their location context.

Literature shows that mLearning has the potential to extend seamless learning. In Muyinda et al. (2010), a mLearning system for seamlessly supporting distance learning students undertaking a field research is reported. Here, the distance researchers are supported variously through text messages. Also, an SMS Broadcast System at Makerere University is receiving wide use from staff wishing to seamlessly provide academic and administrative support services to their students (ibid.).

SAIDE (2008), in a report for the Commonwealth of Learning on using mobile phones for open schooling, has listed several mLearning projects in Africa where seamless learning is evident. These include amongst others: M4girls, where Nokia 6300 phones are loaded with learning objects for supporting and improving mathematics performance of Grade 10 girls in NW province in South Africa; MobilED, which supports informal and formal learning of biology services at Cornwall Hill College and Irene Middle School, South Africa; Dr. Math on Mxit, for collaborative learning in mathematics using instant messaging; MobiDic, for access to dictionary via SMS in South Africa; Eduvision, for access to satellite-distributed content on handheld computers in Kenya; MRSI, for mobile research supervision in Uganda;

Mobi Maths, for learning maths in South Africa; and mobile technology support at the University of Pretoria, for extending academic and administrative support to distance learners. Ford and Botha (2009) have reported on a MobilED project in which learning objects are developed based on the concept of 'mobile audio-wikipedia' (p. 5). This Wikipedia is based on audio mLearning objects. Another project in which audio MLearning objects are developed and utilised is the Hadeda project (Butgereit and Botha 2009). Hadeda is:

> a project where primary school pupils (and even secondary school pupils) are encouraged to practice spelling words using their cell phone. Hadeda allows the language teacher to create spelling lists or vocabulary lists in English and Afrikaans. Hadeda then generates a fun cell phone application using multiple text-to-speech engines to encourage pupils to practice spelling the words. (p. 1)

The development of these and many other seamless mLearning systems have not been underpinned by requirements generated from researched and contextualised MLearning frameworks. Zhang and Looi (2011) and Milrad et al. (2013) have underscored the critical need for researchers and practitioners to put in place effective frameworks and methods for designing, implementing and evaluating innovative learning environments and technologies in different contexts. This is also true for seamless mLearning considering the four (4) questions posed by seamless learning researchers:

- How to design seamless learning activities that support innovative learning practices?
- How to design seamless learning activities that integrate learning across informal and formal settings, with the eventual aim of nurturing autonomous learners?
- How to design learning activities that reflect the cultural diversity of learners?
- How to assess seamless learning in these new educational contexts? (Milrad et al. 2013, p. 7)

Muyinda et al. (2011) have contributed to answering the above questions in their Mobile Learning Object Deployment and Utilisation Framework (*MoLODUF*). The MoLODUF was developed with the aim of guiding system developers to develop pedagogic seamless mLearning systems. As such, this chapter uses the MoLODUF to underpin the generation/instantiation of requirements for the eventual building of a seamless collaborative and cooperative mLearning system for distance learners in hitherto contact universities.

Pedagogically speaking, collaborative and cooperative learning models enable learners to share information in the form of data, files and messages (Ayala and Castillo 2008; Caudill 2007; Uden 2007). In collaborative learning, learners are required to solve a given task as a group, while in cooperative learning, learners share a common knowledge pool for accomplishing individual assignments. Collaborative learning generates a pool of knowledge contributed by learners from different learning contexts which knowledge can form a repository for use in other forms of learning such as cooperative learning. Collaborative and cooperative learning permit disparately located distance learners to virtually co-locate.

Justification for Seamless Learning

In Milrad et al. (2013), a review of a number of seamless mLearning systems reveals that mLearning orchestrates episodic learning 'across learning spaces that contribute to build[ing] learning progressively across contexts and time' (p. 106). Since seamless learning conjures well with anytime-anywhere learning (Zhang and Looi 2011), such a pedagogy is not only suitable to lifelong learners but also to open and distance learners.

With seamless learning in blended open and distance learning, learners can undertake planned face-to-face learning in the classroom, planned individual or group learning outside the classroom and informal learning in- and outside the classroom (Toh et al. 2013). Also, being learners with multiple societal roles, distance learners can use seamless learning to learn as they tend to different chores in life. Technologies which accompany the learner at anytime in anyplace, while partaking of different societal roles, come in handy to abet seamless learning. Mobile devices are a good mediating tool for seamlessly integrating the different learning spaces and roles a learner may find himself/herself in (Toh et al. 2013).

With seamless collaborative and cooperative learning, learners can scaffold each other in their different Zones of Proximal Development (ZPD). According to Vygotsky (1978), learning occurs through mediation in the Zone of Proximal Development (ZPD). The ZPD is the difference between what a learner knows and can do on his/her own and what he/she needs to know and do with the assistance of a knowledgeable member of their society. Mediation in the ZPD is abetted by tools such as the more knowledgeable member or a tool such as an ICT. In our case, through mobile seamless learning, learners can be scaffolded on any learning activity by knowledgeable peers or teachers using a mobile device at anytime in anyplace.

Scaffolding as a teaching and learning strategy can be accomplished through collaborative and cooperative learning (Vygotsky 1978; Uden 2007). Mobile apps such as WhatsApp are well known as good and popular collaborative mobile systems. Even if such systems have affordances of seamless cooperative and collaborative learning, their design is not underpinned by any pedagogical principles or framework. In addition to being underpinned by collaborative and cooperative learning theories, seamless learning can also be underpinned by HCI theories, participatory design theories, design cycle theories, or the MoLODUF. For a detailed insight into theories for seamless learning, see chapters dedicated to that cause in this book. For this chapter, focus is put on using the MoLODUF to underpin the generation of requirements for instantiating a seamless collaborative and cooperative mLearning system.

The MoLODUF

MoLODUF is the Mobile Learning Object Deployment and Utilisation Framework (Muyinda et al. 2011). MoLODUF was developed using Design Research approach (Reeves et al. 2005). This involves five iterative process steps, namely, *Awareness of the Problem*, *Suggestion*, *Development, Evaluation* and *Conclusion*. In the *Awareness of the Problem* process step, the problem at stake was understood from literature and learners' and other stakeholders' points of views. The findings from the *Problem Awareness* process step were used to suggest a tentative design of MoLODUF *in the Suggestion* process step. From the tentative design, MoLODUF was developed in the *Development* process step using inductive reasoning. To test for validity, MoLODUF was subjected to expert evaluation. At the end of it all, the experts agreed on twelve (12) MoLODUF dimensions that could be used for building and evaluating mLearning systems. The MoLODUF which is presented in Fig. 11.1 below and described thereafter has been published in Muyinda et al. (2011).

MLearning Costs Dimension Cost is a central aspect in any mLearning dispensation. This dimension recognises that mLearning is untenable if learners are left on their own to foot its associated communications costs. It implores mLearning developers to put in place mechanisms for mitigating the high cost of mLearning for the mLearner and the institution. The mitigation is possible where the unit cost of mLearning has been established and a mLearning cost sustainability plan put in place.

The unit cost of mLearning is derived from the total cost of mobile phone communication (TCMPC) for a mLearner which is composed of two components, namely, the MLearning and non-MLearning cost components. TCMPC is formally expressed as follows:

$$\text{TCMPC} = \text{Call}(\text{L,O})\,\text{T}_{\text{call}} + \text{SMS}(\text{L,O})\,\text{T}_{\text{sms}} + \text{Data}(\text{L}_{\text{du}},\text{O}_{\text{du}})\,\text{T}_{\text{data}}$$

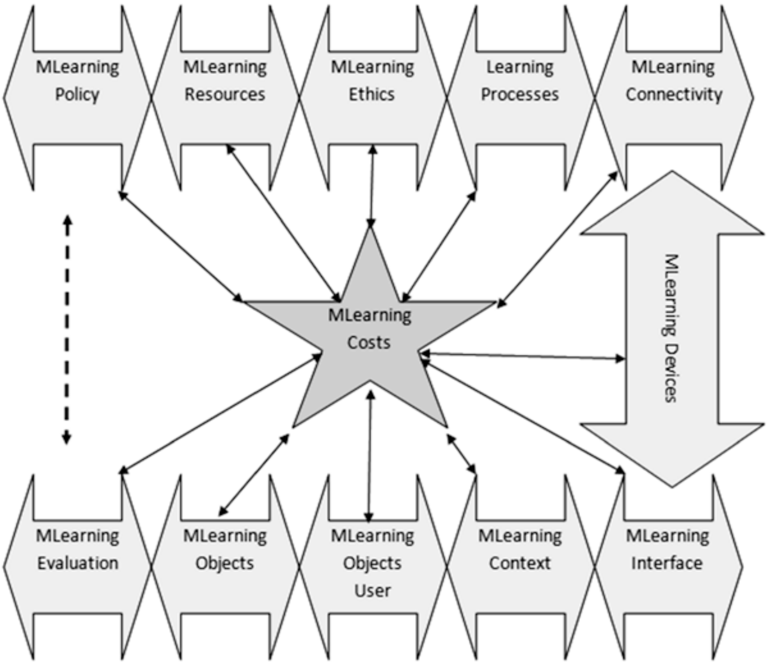

Fig. 11.1 MoLODUF (Adapted from Muyinda et al. 2011)

where

Call (L, O) T_{call} = total cost for calls made for learning and other purposes in a given period

SMS (L, O) T_{sms} = total cost for SMS made for learning and other purposes in a given period

Data (L_{du}, O_{du}) T_{data} = Total cost for data downloaded/uploaded for learning and other purposes

The above formula can be used to disaggregate mLearning costs from other communication costs. Once the actual MLearning cost is ascertained, then a MLearning cost sustainability plan can be implemented.

The mLearning cost sustainability plan (MLCSP) is based on the full commitment to mLearning from telecommunication companies, governments, universities, learners, parents, employers and donors. The plan implores these stakeholders to: provide user-friendly billing and payment mechanisms, empower individual learners to meet their own mLearning bills through provision of part-time jobs, subsidise mLearning services, adopt cheaper communications strategies, provide toll-free mLearning services to registered students, incentivise staff involved in mLearning, showcase unique added learning values in mLearning and have appropriate mLearning policies. When the commitment to this plan is secured from all stakeholders, then mLearning costs can be sustained.

MLearning Policy Dimension MLearning will thrive where there are supportive institutional and government policies. The policies should be able to give guidelines and strategies for using mLearning in universities and other institutions of learning. The mLearning policy dimension seeks to put in place favourable mLearning policies, strategies, regulations and guidelines.

MLearning Resources Dimension This dimension is related to the mLearning cost dimension. MLearning resources include infrastructural, human and financial resources. The infrastructural resources needed for mLearning are servers, fibre-optic backbones, computers, fast Internet connectivity, email, high-end mobile phones, mobile network connectivity, learning management systems (LMS), local area networks (wired and wireless) and mobile applications development software. The human resources needed for mLearning are flexible managers, administrators, lecturers and students willing to experiment with innovations in core educational practices. Other vital mLearning human resources are mLearning researchers and system analysts, mobile application programmers, technicians, instructional and graphic designers and content developers. Financial resources are central for the acquisition, installation and maintenance of all the other mLearning resources. Financial resources are also necessary for sustaining mLearning costs.

MLearning Ethics Dimension This dimension implores developers to take into consideration three ethical issues, namely, amount of cognitive overload anticipated, cultural appropriateness of the content and privacy and security of the m-learner.

Learning Processes Dimension Learning processes are overarching issues in mLearning because they provide all the learning and teaching models commensurate with mLearning (Traxler 2007). The MoLODUF recognises eight (8) learning processes (teaching and learning models) where mLearning can be employed, namely, Co-Creation of New Knowledge, Knowledge Sharing, Collaboration and Interaction, cooperative learning, Reflective Learning, Problem-Based Learning, Academic and Administrative Support and Communication/Information Exchange. Learning processes specify appropriate mLearning activities and determine whether blended learning is needed and whether human intervention (seeded serendipity) is needed in a given learning activity. It is thus necessary to profile existing learning processes with the aim of determining those which are appropriate for mLearning.

MLearning Connectivity Dimension The ability to deploy and utilise a given media type of learning object on a mobile device depends not only on the capability of that device but also on the mobile networking technology at hand. Mobile connectivity state, mobile networking technology at play, mobile service providers and bandwidth available are important factors to consider before deploying a mobile application.

MLearning Devices Dimension MLearning application developers need to profile the mobile devices for use in mLearning object deployment and utilisation. By profiling the mobile devices in use, their generation order, properties, capabilities and limitations can be determined. Mobile device limitations constrain learning (Grant et al. 2007) because of the discomfort they create. This dimension implores developers to introduce and/or increase comfort while using mobile devices if mLearning is to be accepted.

MLearning Interface Dimension The mLearning interface is a very important factor for mLearning acceptance and use. In order to introduce and/or increase learning comfort in mLearning, it is recommended that a blended approach to learning be adopted. A blended approach means that mLearning objects could as well be deployed and utilised on PC interfaces. This has learning objects design implication in the sense that a learning object should be designed for interoperability between mobile devices (mobile device interface) and PCs (PC interface).

MLearning Context Dimension According to Uden (2007) learning context is an important factor in mLearning. A mLearning application should therefore take cognizance of the learner's context because context can propel or inhibit mLearning.

MLearning Object User Dimension The mLearning object user dimension profiles the users of mLearning objects by looking at the learning object user role, profile and education.

MLearning Objects Dimension What form of content/learning objects are you going to deploy and utilise on a given mobile device? This dimension requires mLearning application developers to model the learning objects to be deployed on targeted mobile devices. It implores developers to look into the learning objects' organisation, granulation, media type, accessibility, utilisation, pedagogy, source and brokerage needed for the given mobile device(s).

MLearning Evaluation Dimension 'Evaluation is a reflective learning process' (Lin et al. 1999, p. 43). MLearning evaluation should be done so as to establish whether a mLearning object user has achieved from the content presented in the mLearning object, whether there is learning comfort, whether there is learning equity and whether a deployed learning object actually reached its intended recipients.

The Approach

Quantitative and qualitative research methods underpinned by MoLODUF were employed to collect and analyse data that would eventually contribute to the requirements for seamless mLearning. These included a field survey of learners, interviews/focus group discussion with key stakeholders and review of mLearning literature.

The Field Survey

A survey was undertaken amongst open and distance learning students of Makerere University. Distance learners were preferred because they are always on the move and are to be found in varied contexts (Traxler 2007). The sample size (n) was determined using Calder's (1998) sample size determination formula indicated below:

$$n = \frac{(\text{desired confidence level})^2 * (\text{standard deviation})^2}{(\text{desired level of precision})^2}$$

According to Calder (1998), the standard deviation to be used in his sample size determination formula should be assumed from a standard deviation earlier on calculated on some variable in a related previous study involving the target survey population. Using this assumption, we adopted a standard deviation derived from an evaluation study of the Mobile Research Supervision Initiative (MRSI) at the Department of Open and Distance Learning, Makerere University (Muyinda et al. 2010). Results of the evaluation indicated that a standard deviation of four (4) months was computed on the variable that asked students, who collaborated on mobile phones, to provide the duration they took to complete their field research project paper. We used Calder's assumption and assumed a standard deviation of four (4) in the sample determination formula. Then we chose a confidence level of 95 % ($P < 0.05$) to yield a value of 1.96 in normally distributed data. The desired precision level was set to 0.5. Therefore, at a confidence level of 95 % ($P < 0.05$) and desired level of precision of 0.5,

$$\text{Sample Size}(n) = (1.96 * 4)^2 / (0.5)^2 = 245.86 = 246.$$

The desired minimum sample size was 246. Since surveys are known to have a high non-response rate of even up to 80 % (Burgess 2001), so as to get a return of a minimum of 246 responses, questionnaires were distributed to a sample five times (1,230) the required minimum size of 246. At the end of the survey exercise, 435 fully filled in questionnaires were returned, representing a response rate of 35 %. This was above the 20 % response rate that Burgess (2001) estimated and well above the 246 minimum responses anticipated in Calder's (1998) sample size determination formula.

Multistage sampling involving quota sampling (based on regions) at stage one and stratified random sampling (based on districts) at stage two were employed to select the respondents. Uganda was divided into five regions/quotas (Eastern, Western, South Western, Central and Northern) and then stratified based on districts in each of the regions. From each region we anticipated to draw 252 respondents. The distance learning students' distribution in each of the regions was determined based on the student location register. From each stratum, simple random sampling was used to select the respondents.

Using a self-developed questionnaire underpinned by the dimensions of the MoLODUF, a survey of selected respondents was undertaken. For ethical consideration, the top cover of the survey questionnaire clearly explained to the respondents the purpose of the research and how the results would be treated.

The survey, amongst others, sought to investigate the support services provided to the students by the university and fellow learners, types of mobile phones owned by the learners, their capabilities, the uses they were being put to, possible mLearning activities and mobile networking technologies accessible to the learners.

Interviews/Focus Group Discussions

Interviews and focus group discussions were administered to get qualitative data on learner support activities, intricacies of porting third-party systems into the infrastructure of existing telecommunication companies, factors that could motivate the use of mobile phones in learning and capabilities of mobile phones. Twenty-six (26) key stakeholders were interviewed. The key stakeholders were drawn from students, university academics and administrators, mobile telecommunication companies, telecommunication regulators and SMS aggregators.

Review of Literature

In order to get a better understanding of the requirements for a seamless mLearning system, a literature review was undertaken of existing mLearning systems.

Towards Requirements for a Seamless Collaborative and Cooperative MLearning System

Since the research was underpinned by the MoLODUF, the candidate requirements are adduced from the results of the research following the twelve (12) dimensions of the MoLODUF.

Requirements from the MLearning Costs Dimension

Cost is a critical factor for the success of mLearning. To determine their total cost of mobile phone communication (TCMPC), learners were asked to provide their average monthly airtime cost. The results are presented in Fig. 11.2 below.

Figure 11.2 shows that the learners' monthly airtime cost ranged from USD 0 to 129 per month. The majority of learners (88 %) were able to afford airtime worthy between USD 0 and 24.9 per month, implying that this was the modal class. On average, a student spent USD 13 per months on airtime. Results further indicated that a USD 0 expenditure on airtime was incurred by 9.4 % of the learners and the maximum of USD 129 by just one learner. An airtime expenditure of USD 0 means that the 9.4 % of the learners owned mobile phones but did not top them up with airtime. They used their mobile phones to only receive calls and SMSs. Also, the average monthly airtime expenditure of USD 13 is on the lower side for sufficient collaboration and interaction needed in seamless learning. With an average monthly airtime expenditure of USD 13, a learner subscribing to the a mobile network with a tariff plan of USD 0.19 per minute of voice call and USD 0.08 per text message would have 68 min of voice calls or 162 text messages in a month. This airtime is insufficient considering the fact that mLearning competes with other non-mLearning communication needs as is depicted in the TCMPC formula. Here, the mLearning cost subsidy requirement is adduced.

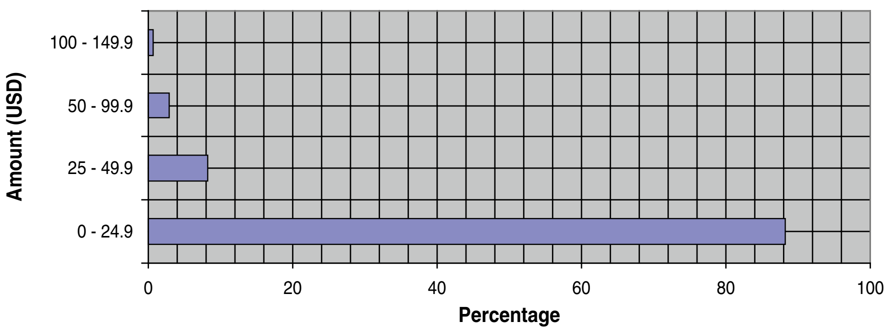

Fig. 11.2 Learners' monthly airtime cost

Requirements from the MLearning Policy and Context Dimensions

The policy environment/context for mLearning was determined by establishing the existing mLearning motivating factors. Through interviews, respondents were asked, 'what do you think are the factors that could motivate the use of a mobile phone for learning?' Numerous responses were received and coded around six (6) themes. The six themes were then ranked from the most frequent (1 being the most frequent, 2 the lesser frequent and so on) to the least frequent. The themes are presented in Table 11.1 below.

Results in Table 11.1 indicate that a favourable policy environment and context for mLearning exists. Thus, a seamless mLearning system should have mechanisms for harnessing the positive policy regime and context.

Requirements from the MLearning Resources Dimension

Results from interviews and focus group discussions revealed the infrastructural, human and financial resource requirements for seamless mLearning. The requirements were categorised into two – (1) those needed by the institution and (2) those needed by the m-learner.

As far as institutional infrastructure requirements are concerned, seamless mLearning requires servers for hosting the back-end database, mLearning system and learning management system, local area network, high-speed Internet connectivity, personal computers/laptops, mobile phones and mobile applications development software. As for the students, the infrastructures needed to integrate mLearning into their pedagogical processes are smartphones and GSM/GPRS mobile network connectivity.

For human resources, the study confirmed that the institution requires mLearning system analysts, researchers, programmers and technical support at the back end. At the front end, the institution requires flexible managers, administrators, lecturers,

Table 11.1 Factors that could motivate mLearning

Factors	Frequency	Rank order
Increasing permeation of mobile phones amongst the populace	67.7 % (n=18)	1
Increasing coverage of mobile telecommunication networks	64.6 % (n=17)	2
Government policies on telecommunication investments	57.4 % (n=15)	3
Existing eLearning infrastructure	44.8 % (n=12)	4
Emerging of distance learning units in conventional universities	21.3 % (n=06)	5
The emerging of mobile applications	4.5 % (n=01)	6

Source: Primary data

m-instructional and graphic designers, m-content developers and students willing to experiment with innovations in core educational practices. Human resource requirements from the students' viewpoint relate to a well-sensitised student body about the benefits and challenges of mLearning.

As for financial resource requirements, the institution requires to: (1) procure and subscribe to SMS and USSD codes, (2) pay for SMS aggregation services, (3) pay for USSD hosting services and (4) meet costs for in- and outbound traffic. The students require financial resources to fund in- and outbound traffic.

Requirements from the MLearning Ethics Dimension

Respondents were wary about a learning system which would jeopardise their security and privacy. One of the lecturers interviewed said, '… if mLearning is not going to interfere with my freedom to rest at night, then I will accept it'. A respondent from the communications regulatory commission said, '… it is against the law to push unsolicited text messages to people'. Therefore, to abide by the regulations, the mLearning system should enable people to voluntarily subscribe and unsubscribe to/from it at will. This will enable them to belong to groups they prefer and therefore avoid information overload which is a receipt for cognitive overload.

Requirements from the Learning Processes Dimension

Under this dimension, the study profiled the learner support activities provided by the university and those provided by learners themselves. For support services provided by the university, the study established that distance learning students at Makerere University interfaced face to face with their lecturers and fellow learners for a period of four (4) weeks in a semester of fifteen (15) weeks. In the remaining eleven (11) weeks, they were left on their own but had to be virtually or physically supported. Table 11.2 below provides the support services provided to the ODL students by the university.

Besides providing face-to-face support at the main campus for 4 weeks in a semester of 15 weeks, the university also provided academic, administrative and social support to students. According to findings in Table 11.2 below, the number one support that students receive from the university was provision of information about different learning events. This information was provided through fliers, notice boards, radio and at learning centres. According to one of the interviewees, '… this support helps us connect distance learners to their university'. Mobile notice board, where learners can push and pull information, would suffice in implementing most of the elements in Table 11.2 below.

Likewise ODL learners supported themselves during self-study periods. Table 11.3 below provides the student-student support services that occurred. From this table, it is evident that peer-to-peer support amongst distance learning occurred

Table 11.2 Support services provided to distance learners by the university

Support services	Yes	No
Provision of information about different learning events	66.7 % ($n=290$)	33.3 % ($n=145$)
Provision of coursework advice	56.6 % ($n=246$)	43.4 % ($n=189$)
Provision of guidance on learning materials	30.1 % ($n=131$)	69.9 % ($n=304$)
Provision of administrative information	24.6 % ($n=107$)	75.4 % ($n=328$)
Provision of support services through the LMS	16.3 % ($n=71$)	83.7 % ($n=364$)
Provision of study materials	12.4 % ($n=54$)	87.6 % ($n=381$)
Provision of tutorials at study centres	10.8 % ($n=47$)	89.2 % ($n=388$)
Provision of guidance and counselling services	10.3 % ($n=45$)	89.7 % ($n=390$)
Provision of registration services	9.9 % ($n=43$)	90.1 % ($n=392$)
Provision of academic consultations	9.7 % ($n=42$)	90.3 % ($n=393$)

Source: Primary data

Table 11.3 Peer-to-peer support services amongst distance learning students

Support services	Yes	No
Accomplish group assignments/coursework	77.7 % ($n=338$)	22.3 % ($n=97$)
Undertake group discussions	77.0 % ($n=335$)	23.0 % ($n=100$)
Keep one another updated on learning events	66.7 % ($n=290$)	33.3 % ($n=145$)
Help each other in accomplishing individual assignments	56.6 % ($n=246$)	43.4 % ($n=189$)
Help each other in understanding difficult content	30.1 % ($n=131$)	69.9 % ($n=304$)
Give one another examination/test tips	28.3 % ($n=123$)	71.7 % ($n=312$)

Source: Primary data

mainly for the purpose of group learning activities, which included: accomplishing group assignments (77.7 %) and discussions (77.0 %). Individual support was also evident where students informed their friends about different learning events at the main campus (66.7 %), tutored each other on individual assignments (56.6 %) and difficult to understand content areas (30.1 %) and gave each other examination/test tips. This support could be enhanced by systems that seamlessly spur group and individual learning. Group learning is mainly achieved through collaborative learning while individual learning is mainly achieved through cooperative learning (Ayala and Castillo 2008; Caudill 2007; Uden 2007).

Requirements from the MLearning Connectivity Dimension

Even if a learner owned a mobile phone with high-end features, the capabilities of the mobile networking technologies availed by the telecommunication service providers dictated the media form of content that could be accessed on such a mobile phone. Learning content can be expressed either as text, audio, video, graphics or mixed media. Interviews with telecommunication service providers revealed that Bluetooth, Wi-Fi, GSM, GPRS, 3G, WiMax (cellular broadband) and EDGE networking technologies were available to their clients but the most common connectivity was gained via GSM. This dictates that the seamless mLearning system should be based on GSM connectivity.

Requirements from the MLearning Devices Dimension

ODL students were profiled for ownership of mobile phones and technical capabilities and limitations of those phones. The results revealed that 97.7 % of the students surveyed owned a mobile phone while 100 % of them had access to a mobile phone service. There were a myriad of mobile phone types and models with low- through to high-end features. Their technical capabilities and limitations varied. Table 11.4 below shows the capabilities of learners' mobile phones.

For learners to be able to connect to the Internet and access any learning resources and services using their mobile phones, the GPRS feature is considered the most important and relevant of all features on the phone. From Table 11.4 below, it can be seen that 56.3 % of the learners surveyed had the GPRS feature on their mobile phones. About 34.0 % of the learners did not have the GPRS feature while 9.4 % were not sure whether their mobile phones had a GPRS feature. On average, 18.2 % of the learners were not sure of the presence of high-end features on their mobile phones while only 32 % of the learners had mobile phones with high-end features. Low-end mobile phone features are synonymous with most basic mobile phone, e.g., Nokia 1110, while high-end mobile phones features are to be found in smartphones. Since the majority of the learners owned low-end mobile phones, a seamless mobile application in this context should be portable on low- through to high-end mobile phones. MLearning systems are influenced by the capabilities and limitations of mobile devices (Caudill 2007; Grant et al. 2007).

Table 11.4 Capability of learners' mobile phones

High-end mobile phone features	Available	Not available	Not sure
General packet radio service (GPRS)	56.3 % (n=245)	34.3 % (n=149)	9.4 % (n=41)
Bluetooth	28.0 % (n=122)	55.9 % (n=243)	16.1 % (n=70)
Wireless Access Protocol (WAP)/ Wireless Fidelity (Wi-Fi)	33.6 % (n=146)	53.8 % (n=234)	12.6 % (n=55)
Global Position System (GPS)	18.9 % (n=82)	56.3 % (n=245)	24.8 % (n=108)
Radio frequency identification (RFID)	23.4 % (n=102)	48.7 % (n=212)	27.8 % (n=121)
Average	32.0 % (n=139)	49.8 % (n=217)	18.2 % (n=79)

Source: Primary data

Requirements from the MLearning Interface Dimension

The study established that tutors and administrators of distance learning students at Makerere University had access to mobile phones and Internet ready personal computers. On the other hand, only 23 % of the distance learners could get hassle-free access to tethered Internet ready PC. For the tutors and administrators, a seamless system should be interoperable between mobile and PC interfaces, while for learners, the main interface for the seamless system should be based mainly on a mobile phone interface.

Requirements from the MLearning Object User Dimension

The study found out that distance learners had multiple social and economic responsibilities and were more mobile than their counterparts, the conventional students. A seamless mLearning system would be more beneficial to distance learners than conventional learners.

MLearning Objects Dimension

MLearning object deployment is greatly influenced by the possible functionalities/capabilities of the learners' mobile devices and what they use them for. These are presented in Tables 11.5 and 11.6 below.

Table 11.5 Possible functionalities on learners' mobile phones

With my mobile phone I can …	True	False
Make/receive voice calls	100 % (n=435)	0.0 % (n=0)
Send/receive text messages	100 % (n=435)	0.0 % (n=0)
Record audio and play it back	43.2 % (n=188)	56.8 % (n=247)
Access the Internet	42.1 % (n=183)	57.9 % (n=252)
Send/receive emails	41.6 % (n=181)	58.4 % (n=254)
Take/send/receive a photograph	40.5 % (n=176)	59.5 % (n=259)
View documents and images	34.3 % (n=149)	65.7 % (n=286)
Use Bluetooth technology	27.8 % (n=121)	72.2 % (n=314)
Record and view videos	22.3 % (n=97)	77.7 % (n=338)
Install mobile applications on it	19.3 % (n=84)	80.7 % (n=351)
Interact with the applications installed on it	18.4 % (n=80)	81.6 % (n=355)
Read, edit and handle computer files	15.9 % (n=69)	84.1 % (n=366)

Source: Primary data

Table 11.6 Possible mLearning activities currently partaken of by students on their mobile phones

I have ever used my mobile phone to:	Yes	No
Interact/be in touch with my classmates	77.7 % (n=338)	22.3 % (n=97)
Send/receive reminders of learning events	66.7 % (n=290)	33.3 % (n=145)
Send/receive coursework advice to/from classmates	56.6 % (n=246)	43.4 % (n=189)
Be in touch with university officials	39.3 % (n=171)	60.7 % (n=264)
Receive guidance on learning activities from lecturers	30.1 % (n=131)	69.9 % (n=304)
Send/receive examination/test tips to/from classmates	28.3 % (n=123)	71.7 % (n=312)
Receive administrative messages from the university	24.6 % (n=107)	75.4 % (n=328)
Discuss topics covered in a given course	23.2 % (n=101)	76.8 % (n=334)
Access/deliver online learning material/content	16.3 % (n=71)	83.7 % (n=364)
Supplement print-based learning materials/content	12.4 % (n=54)	87.6 % (n=381)
Undertake simple multiple choice quizzes	10.8 % (n=47)	89.2 % (n=388)

Source: Primary data

Table 11.5 above shows that all (100 %) learners who had mobile phones could place and receive voice and text messages. These are functionalities which cut across the continuums of all mobile phone generations, brands and families. Table 11.5 further indicates that high-end mobile phone functionalities were possible on mobile phones of between 15.9 and 43.2 % of the learners as is shaded in Table 11.5 above. Since the majority of learners have low-end mobile phones, seamless mLearning for such learners should be presented using learning objects that are compatible with low-end mobile phones. Such learning objects can take the form of SMSs/text and audio media. Lee and Tynan (2009) have used audio podcasts for supporting distance learning students.

So as to compare the mobile phone functionalities with the kind of use put on them, learners were asked to provide learning activities they partook of on their mobile phones. The results are presented in Table 11.6 above.

Table 11.6 above shows that learners were using their mobile phones to partake of different learning objects. The learning objects partaken of were mainly for extending learner support activities. For instance, the majority of students (77.7 %) were enabled to interact/be in touch with each other. This interaction could abet collaborative and cooperative learning. Also, since the survey participants consisted of distance learners, the mobile phone reduced the loneliness of 77.7 % of the learners. Thus, a seamless cooperative and collaborative system would be most beneficial to distance learners.

Requirements from the MLearning Evaluation Dimension

This dimension is intended to inform the developer about the consequences of his/her development in as far as learning is concerned. Do learners understand the content presented therein? Is there learning comfort? Is there learning equity in seamless learning? Do all learners receive the content intended for them? Mechanisms for imparting learning comfort in mLearning and for informing the lecturer/administrator about learning object delivery to intended recipients are vital in a seamless mLearning system.

Summary of Requirements

From the findings above, the requirements in Table 11.7 below are adduced.

Seamless Collaborative and Cooperative MLearning System Prototype

From the requirements adduced, a prototype for a seamless mLearning system capable of offering academic and administrative support has been developed. The prototype's academic component is underpinned by the collaborative and

Table 11.7 Summary of adduced requirements

Dimension	Requirements
MLearning costs	Communication cost subsidies
MLearning policy	Mechanisms to harness the positive policy elements
MLearning resources	SMS code, SMS code aggregation and hosting, mobile telecommunications network backbone, hardware and software, programmers, mLearning system analysts, lecturers, administrators
MLearning ethics	User authentication
Learning processes	Collaborative and cooperative learning
MLearning connectivity	Connectivity via GSM or GPRS
MLearning devices	Low- to high-end mobile phones and PCs
MLearning interface	Mobile and PC interface
MLearning context	Mechanisms to harness the positive context
MLearning object user	Distance learners, lecturers, administrators
MLearning objects	Text and audio media types
MLearning evaluation	Mechanisms for learning comfort, mechanisms for learning object delivery feedback

cooperative learning paradigm because findings indicated these as being the most easily achievable mobile learning processes and most beneficial to the distance learner. On the other hand, the prototype's administrative component is underpinned by the push and pull information access strategy because findings have indicated that distance learners used their mobile phones mainly for information access and interaction.

The Prototype Collaborative MLearning Component

The teaching and learning strategy (learning process dimension) underpinning this component is collaborative learning. It was implemented in a component dubbed Collaborative Virtual mLearning (Colla VmLearn). The component is aimed at enhancing collaborative working amongst disparately located distance learning students (mLearning object user dimension). For devices, it utilises a range of low- through to high-end mobile phones since the study established that learners had a multitude of mobile phones (mLearning device and context dimensions). It also restricts itself to the use of text messages as the learning objects (mLearning objects dimension) because these are portable across the continuum of all mobile phone interfaces (mLearning interface dimension). The component is accessible through GSM and GPRS mobile connectivity (mLearning connectivity dimension). Learners have to enrol themselves onto the system and join different groups before being allowed to use the system (mLearning ethics dimension). To participate in collaborative learning, learners are charged per SMS sent and the feedback SMS is charged on the institution (mLearning cost dimension). The component is supported by an SMS short code acquired and subscribed to at fee (mLearning resources dimension). An SMS aggregator aggregates all traffic to and from different telecom companies at a fee (mLearning resources dimension). The component was piloted for feedback (mLearning evaluation dimension). The Colla VmLearn interoperates between mobile phones and personal computers (mLearning interface dimension).

The Colla VmLearn prototype works in the following way. Using a PC interface, a lecturer sets a question for group discussion. For example, 'Why are radians preferred to degrees?' The system is programmed in such way that it automatically assigns a code (say 000001) to each discussion question set and is sent as an SMS to a designated group of learners.

The message received on the learners' mobile phone will look like this:

Why are radians preferred to degrees? – 000001

The learners in the group can then compose a short answer and package it as an SMS to be sent back as a response to the question.

The response SMS syntax looks like this:

A <Question Code> <Response to Question>

or after fitting in the syntax

A 000001 rad are commonly used SI units as opposed to degrees

where 'A' is a prefix indicating to the system that it is an answer

The response SMS above is then sent to a designated short code (say 8004). The short code is given to the learners in advance.

The answers from the different discussants are rerouted (via an SMS aggregator), as SMS messages, to the different learners subscribing to the target group. The answers are also aggregated as response discussion threads in the LMS for learners to see later when they get access to an Internet connection and access the LMS either via their Internet ready mobile phones or Internet-connected PCs. The responses in the thread can then be aggregated by the group secretary to form an essay for the group. This way, collaborative learning/working is achieved.

The Prototype Cooperative MLearning Component

The teaching and learning strategy (learning process dimension) underpinning this component is cooperative learning. This component was implemented in a component dubbed Cooperative Virtual mLearning (Coop VmLearn). The component was aimed at enhancing knowledge sharing amongst disparately located distance learning students (mLearning object user dimension). Just as the Colla VmLearn, the design of the Coop VmLearn was also underpinned by the requirements adduced from the research.

The Prototype MLearning Administrative Component

This component was built following the push and pull information access strategy. It subsumes the functionality of a physical notice board. The component was dubbed the Virtual mLearning Notice Board (VmNoB). It saves distance learners from the hassle of travelling to the main campus to get information from physical notice boards. In this component, an administrative information repository is built for learners to seamlessly access with their mobile phones on demand. Its implementation can be based on USSD technology, but in the prototype under caption, it was based on SMS technology due to high cost of acquiring and subscribing to a USSD code (mLearning resources dimension). Figure 11.3 below shows the architecture of the VmNoB.

From the architecture in Fig. 11.3, a Bachelor of Education (BED) learner wishing to establish the contact information of his/her head of department will compose an SMS and send it to the given short code (in the case of this study 8004) as is seen in Fig. 11.4 below.

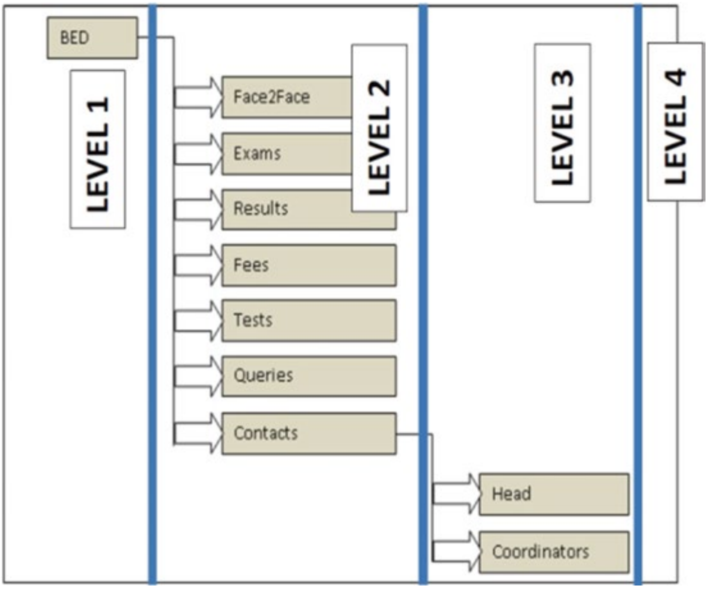

Fig. 11.3 The VmNoB architecture

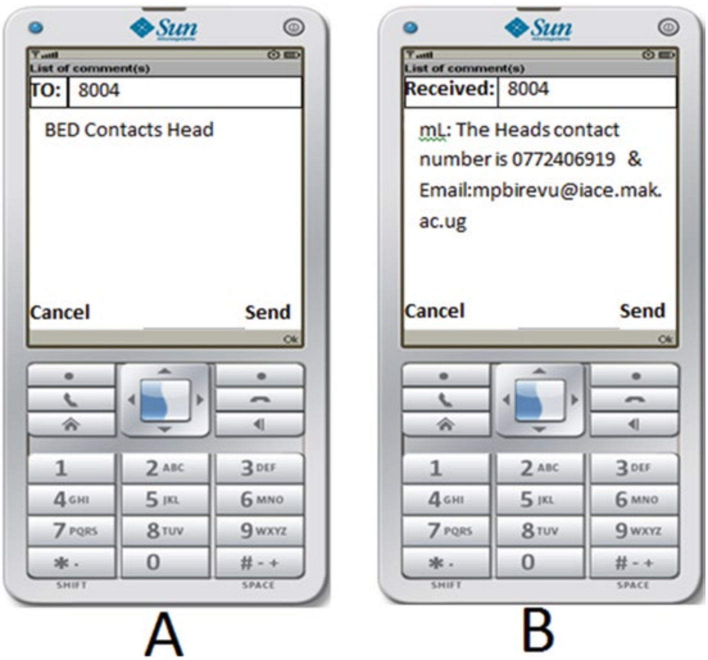

Fig. 11.4 The VmNOB syntax

The success of the VmNoB depends entirely on the richness of information repository created by an institution for access through the mobile phone. As is seen in Fig. 11.4 above, the keyword levels in the syntax architecture can be expanded.

Summary and Conclusion

This chapter has shown that MoLODUF can be used to instantiate requirements for a seamless collaborative and cooperative mLearning system. It has answered four pertinent questions in the field of seamless learning. It has shown that seamless collaborative and cooperative learning practices can be achieved through requirements generated using the MoLODUF. It has also demonstrated that learning activities that integrate learning across formal and informal contexts are achievable through mobile collaborative and cooperative learning. Also through group solutions derived from collaborative working, a reflection of the cultural diversity of learners is made apparent. All in all, the MoLODUF presents a robust method for developing seamless mLearning systems. Further research is recommended in the area of determining the learning achievements gained out of the seamless learning attained from the collaborative and cooperative mLearning systems instantiated from the MoLODUF.

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Chapter 12
Scripting and Orchestration of Learning Across Contexts: A Role for Intelligent Agents and Data Mining

Mike Tissenbaum and James D. Slotta

Abstract This chapter describes a 12-week physics curriculum that engaged students as a knowledge community across contexts: in their classroom, home, neighborhoods, and in the smart classroom. In order to support the curriculum intervention, we developed two complementary technology environments that are built on SAIL Smart Space (S3) – an open-source technology framework. Using a design-based research methodology, we instantiated an orchestrational framework that included the use of social tagging and metadata. Additionally, we devised intelligent agents to support the enactment of our collaborative inquiry scripts. We identify three important structural dimensions for which intelligent agents can play a key role in the orchestration of such curricula: Content Agents, Activity Structure Agents, and Grouping Agents. We conclude with an evaluation of these agents in support of our curriculum designs and propose a set of design principles for the role of intelligent agents and data mining in supporting cross-context learning.

Introduction: New Opportunities for Learning Across Contexts

In recent years, we have witnessed a change in the ways in which students are engaging with the world around them. Over two thirds of Americans now have Internet access at home, and the majority of teens are now actively engaged in the creation of online content (Bull et al. 2008). Outside of school, students are increasingly driving their own learning, by finding relevant resources or connecting to online interest groups, using Internet or cellular network technologies to mediate their interactions (Sefton-Green 2004). These new practices are familiar to students, who have grown up with a "Web 2.0" landscape, where users are the active creators, commenters, and classifiers of the products and processes with which

M. Tissenbaum (✉) • J.D. Slotta
University of Toronto, Toronto, ON, Canada
e-mail: miketissenbaum@gmail.com

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they interact, including the construction and organization of knowledge (Dohn 2009). Such user-created content can take on many different forms, from collections of user-contributed artifacts (e.g., Flickr, YouTube), to community-generated social spaces (e.g., Facebook, ResearchGate), to collaboratively generated and edited evolving content (Wikipedia), to news feeds or other socially filtered resource streams (e.g., Reddit). Even games and leisure spaces are now deeply infused with a social component (e.g., World of Warcraft, Fantasy Sports). There is evidence that such "user-contributed content" (Vickery and Wunsch-Vincent 2007) promotes deeper engagement with the content and the learning community, because users see themselves as participating in the community's progress (Tedjamulia et al. 2005) and because of the awareness of "having an audience" (Wheeler et al. 2008). Despite the explosive growth of these practices in many domains, and their increasing importance to everyday life in the twenty-first-century knowledge society (Zuboff and Maxim 2004), schools have generally failed to adapt them into regular curricular designs (Buckingham 2007).

The growth of user-contributed content is paralleled by the rapid advancement of technologies that support users in connecting and participating in these communities. Common to many of these technologies is the use of metadata (i.e., data about data; Wiley 2000), which can be both user generated or system generated. User-generated metadata often takes the form of tagging, in which participants assign keywords to objects within the system (e.g., photos, videos, narratives, or other users). System-generated metadata can be generated automatically to capture complex underlying information about both the users of the system (e.g., assigned roles, group memberships, times logged into the system) and the products of their interactions (e.g., created artifacts, votes cast, pages visited). Connecting this metadata to semantic ontologies (e.g., to well-defined categories such as "tags," "groups," or "roles") can provide avenues for connecting seemingly disparate pieces of information within a community's knowledge base (Anderson and Whitelock 2004). This semantic metadata can also be leveraged to coordinate access to materials and activities, group assignments, and other logical functions of the system (Simon et al. 2004; Zhao and Okamoto 2011).

The use of metadata to make connections between individual students and the products of the larger class community becomes particularly powerful when researchers wish to extend learning beyond the traditional classroom walls. Social and semantic metadata can create a "chain" that connects student learning across formal and informal learning contexts (in class, at home, in the field, or in their neighborhoods) and across diverse time scales versus traditional single class periods (Milrad et al. 2013). Sometimes referred to as "seamless learning" (Chan et al. 2006), this approach can empower learners to engage with their learning community's knowledge base, whenever and wherever they are situated (Wong and Looi 2011). With more than two thirds of young adults now owning a web-enabled smartphone in the United States (Pew 2012[1]), there is a growing technological capability for students to engage with their learning community "on the go." Such

[1] http://www.pewinternet.org/Reports/2012/Smartphone-Update-Sept-2012.aspx

capabilities are not in themselves sufficient to ensure effective learning designs, but fortunately they also provide new opportunities for research of such learning. Because research has typically focused on either formal or informal learning and not on the synergistic connection across contexts and environments (Looi et al. 2010), a central goal of seamless learning is to develop curricular interventions where students access and contribute to community knowledge across diverse learning contexts and scales of time (Wong and Looi 2011). This challenge entails the design of user interfaces, including the representation of community knowledge, and how information is used and contributed meaningfully by students across distinct contexts.

Scripting and Orchestration

Curricular designs that include student-contributed content and learning across contexts are likely to be more complex and dynamic than in previous generations of computer-supported learning (Slotta 2010). Designs must now include the configuration (and possibly the dynamic reconfiguration, based on emergent metadata) of student groups and activities, the technologies used, and critical roles for the teacher. Even in traditional classroom settings, when left to their own devices, students often struggle to choose the most appropriate strategies, understand the goals, or the nature of the task (O'Donnell and Dansereau 1992). Thus, in designing curricula that span multiple intertwined learning contexts, we must carefully configure the structure of the interactions, roles, goals, and interaction patterns in the form of pedagogical "scripts" (Kaplan and Dillenbourg 2010). These scripts have a macroscopic aspect that describes the overall curriculum and timing of individual activities (e.g., a field trip, or a homework task) and a microscopic aspect that specifies individual activities at the fine-grained detail of specific materials, tools, and learning goals (Tissenbaum and Slotta 2012). The design of both the macro- and microscripts must address the content of the learning domain, including the specific learning goals for students.

The enactment of such carefully designed scripts is typically scaffolded with computer-based learning environments such as WISE (Slotta and Linn 2009) or with scientific experimentation environments such as Vlab (Tsovaltzi et al. 2008). With the growth of mobile technologies, new technology environments have been developed to support student observations in museums (Kuhn et al. 2012), university campuses (Kohen-Vacs et al. 2011), or environmental field trips (Zimmerman and Slotta 2003). A fundamental challenge to seamless, cross-context learning will be the integration of such learning environments, allowing students to experience a productive, engaging "macro-script" that includes distinct micro-scripts within each context.

There is a parallel challenge of coordinating students and teachers during the enactment of such scripts. This process of supporting the execution of these scripts, both in real time and across longer scales of time, is often referred to as orchestration

(Dillenbourg et al. 2009). The orchestration of curricular scripts needs to be flexible enough to allow for the emergence of new ideas, themes, and avenues for investigation (Slotta 2010). As these scripts become more complex, the information processing needs of both teachers and students increase significantly, requiring designs to consider the "orchestrational load" of participants (Dillenbourg et al. 2011). In managing the orchestrational load of the classroom, designs need to take into account the various actors' informational and regulatory needs and distribute this load among the participants, materials, and technologies present within the learning environment (Sharples 2013). Students need to make sense of their place within the script, their role within the class, and how to access relevant materials within an evolving knowledge base. Similarly, teachers must be aware of what is happening on individual, small group, and whole class levels; the timing and progress of activities; the state of knowledge within the class; and potential points of intervention within the script. To respond to such challenges, technological supports must support the flow of materials, the scaffolding of activities, and the real-time processing of user interactions to inform student (self-regulated)- and teacher-mediated orchestration. Cuendet and Dillenbourg (2013) suggest that the use of distributed interfaces, spreading orchestrational information and regulatory process across multiple interfaces, can be a successful strategy for reducing orchestrational load. This approach becomes especially powerful in smart classroom designs in which the multiple modalities of the room (e.g., tablets, screens, interactive tables and walls, paper artifacts) all disappear into a single unified classroom ecosystem (Cuendet and Dillenbourg 2013).

Intelligent Agents for Scripting and Orchestration

One approach to such orchestration is seen in the application of "intelligent software agents" – small, active software elements that can respond to current context, or past actions of participants, performing real-time data-mining operations and operating on semantic metadata (Brusilovsky 2001). For example, the assignment of students to groups and the assignment of materials to groups can be informed dynamically by processing the metadata of what materials students have worked on previously or their location within the physical environment (Tissenbaum and Slotta 2013). Intelligent agents hold particular promise in support of inquiry learning, in part because they allow orchestration of scripts that are deliberately ill determined at the outset of orchestration (i.e., scripts where it is not known, a priori, what outcomes or conditions will emerge from the products of student interactions). The use of intelligent agents allows for such open-ended designs that allow the script to evolve in relation to student interactions (Slotta 2010).

These new forms of evolving curricular scripts are well suited to the design and enactment of activities where students contribute to and make use of the growing knowledge base in learning activities across multiple contexts. To the extent that any learning activities depend on student-contributed materials, it is not actually possible to know in advance the complete content or structure of such activities. Metadata, such as student-generated tags or votes, will emerge as a result of the enactment, and activity sequences may be scripted such that they depend on those emergent features. We identify three important dimensions of structure, for which intelligent agents can play a key role in the orchestration of such curriculum:

1. Content Agents
   This refers to the use of intelligent agents for managing, building, and retrieving content. What is the current domain of a student's inquiry, and what learning context, group, or tool are they learning? By understanding the content that students are, or have been, working on, intelligent agents can update students on changes to that content or connect it to other artifacts for knowledge work. Agents also have the opportunity to inject materials into the script, e.g., by populating a student's "drawer" (within a particular learning environment) with all content materials that are tagged by students – even those appearing in real time.
2. Activity Sequencing Agents
   As student- and system-generated semantic metadata emerge, data-mining agents can connect users with materials, as described above, but can also make assignments to learning activities or conditions. Sequencing agents can process a student's interactions while also monitoring global (i.e., community level) metadata, to determine the next activity, tool, or location for the student. In this way, the script does not have to be identical for all students and can be seen more as a map of activities that students can traverse in many pathways. Sequencing agents help determine what parts of the map may be accessible, in accordance with emergent metadata and scripting logic.
3. Grouping Agents
   The ability to know the history of student interactions, both individually and as part of the larger community, allows for the design of intelligent agents that can dynamically group or sort students according to specific pedagogical logic. This has particular significance in managing the orchestrational load for teachers, by helping track and manage which students have worked with whom, what materials students have covered in past activities, or any groups (e.g., tasks or expertise groups) to which they have previously been assigned. Intelligent agents can group students with peers according to metadata that is emerging in real time – which would be practically impossible for any human to do in real time.

New Pedagogical Models for Collective Inquiry

The new technology affordances and pedagogical constructs described above present challenges for teachers and researchers to design pedagogical applications that include user-contributed content and cross-context learning. Educators require clear models of how to engage students in such learning, connecting their personal activities meaningfully into a larger social construct and supporting activities across long spans of time and various contexts. One approach to the integration of Web 2.0 tools and practices is that of knowledge communities, where students are asked to see themselves as a collective learning unit, with a high level of responsibility for defining their own learning goals and activities (Brown and Campione 1996; Scardamalia and Bereiter 1994; Bielaczyc and Collins 1999). In a knowledge community, students contribute content to a central "knowledge base" where it is accessible to all peers in the community as a resource for subsequent inquiry activities (Slotta and Najafi 2010). Ideas can also be refined or improved by members or synthesized into higher-order learning objects (Scardamalia and Bereiter 2006). Despite its clear relevance to the needs of twenty-first-century learning, the knowledge community approach has not been widely adopted by teachers or researchers, due in part to the high demand that it places on teachers. This is particularly true in domains with substantive demands for content learning, such as secondary math and science, where teachers do not feel that they have the luxury of encouraging their students to work as a knowledge community and define their own learning objectives (Slotta and Peters 2008).

To make the knowledge community approach more accessible to teachers, Slotta and his colleagues have developed the Knowledge Community and Inquiry (KCI) model (Fig. 12.1), which specifies a set of design principles for a knowledge community approach for secondary science (Slotta and Najafi 2013). In KCI, students work collectively, contributing, tagging, and improving content in a shared knowledge base that serves as a resource for subsequent inquiry. Inquiry activities are carefully designed so that they engage students with targeted content and provide assessable outcomes, allowing students some level of freedom and flexibility but ensuring progress on the relevant learning goals. KCI curriculum requires a substantive epistemic shift away from didactic presentation of content (where students work

Fig. 12.1 Knowledge community and inquiry (KCI) model

largely under the guise of individual learners) and toward a collective understanding of progress and activity. KCI guides the design of complex inquiry activities that span multiple student configurations (individual, small group, and whole class) and contexts (in class, at home, in the field). Within a KCI curriculum, which can span weeks or months, students explore and develop ideas using technology-enhanced materials, tools, and interactive simulations. These activities are carefully scripted in order to address specific learning goals; however, the script itself must be flexible enough to allow for the emergence of new ideas and community voice. This may include the development of technologies that allow the teacher to easily author new activities, scaffolds, or prompts in response to these emergent factors. As part of the development of KCI, we have established a set of design principles that guide the creation of individual, cooperative, collective, and collaborative scripts and activities and how these are scaffolded.

New Technology Supports for Collective Inquiry

In order to support the curriculum where students are engaged collectively in sustained inquiry, researchers have developed technology environments that scaffold student learning and support the growth and procedure of the knowledge community. Scardamalia and Bereiter (2006) have argued that such environments must be aligned with the underlying epistemic goals of the approach. They developed an environment called Knowledge Forum, largely because existing technologies could not support the types of interactions demanded by their theoretical principles of knowledge building. Thus, any technology environments employed within such a knowledge community approach are more than just tools or workspaces, but, rather, they serve as an integral part of the community's distributed intelligence and are intrinsic to the community's notions of learning and intelligence (Pea 2004).

In order to successfully enact the kinds of complex designs required for KCI, we needed a flexible and adaptive infrastructure that could support the design and orchestration of collaborative activities that include spatial, social, and semantic dependencies. To this end, we have developed SAIL Smart Space (S3), an open-source framework that coordinates complex pedagogical sequences, including dynamic sorting and grouping of students and the delivery of materials based on emergent semantic connections. S3 has been developed to allow the physical space of classrooms or other learning environments to play a meaningful role within the learning design – either through locational mapping of pedagogical elements (e.g., where different locations are scripted to focus student interactions on different topics) or through orchestrational support (e.g., where physical elements of the space, like projected displays, help to guide or coordinate student movements, collaborations, or activities). S3 was also developed to add a level of intelligence to classrooms or other learning environment, including real-time data mining and computation performed by intelligent agents to support the orchestration of inquiry scripts. In addition, we are also investigating the role of ambient displays

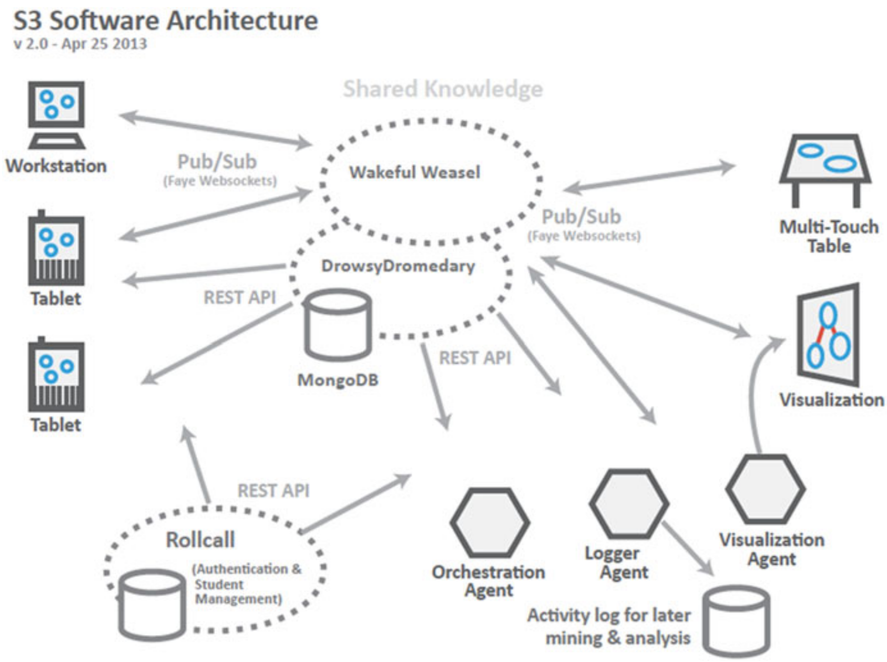

Fig. 12.2 SAIL smart space (S3) systems architecture, showing the use of direct WebSocket messaging to enable communications among any element of the environment, a persistent, non-relational (no SQL) database (MongoDB) and intelligent agents

of information, within the physical environment, as a means of providing "peripheral" guidance or feedback (Alavi et al. 2009).

At present, S3 includes a set of core technologies: (1) a portal for student accounts and software application management, (2) an intelligent agent framework for data mining and tracking of interactions in real time, (3) a central database that houses the designed curriculum and the products of student interactions, and (4) a visualization layer that controls how materials are presented to students (see Fig. 12.2). Our goal in developing S3 was to support a broad program of research on collaborative inquiry, allowing for more rapid development of learning materials and environments. While it is not designed as an off-the-shelf solution, S3 is offered as an open-source framework, in hopes of promoting wider access to such functionality and growing a community of developers within the learning sciences (Slotta et al. 2012).

This paper presents an application of KCI and S3 to enable seamless learning across contexts, including user-contributed, tagged, and coedited materials, and a role for intelligent agents in coordinating a complex sequence of student activities. Working closely with a high school physics teacher, we designed and developed a 12-week physics curriculum where students engaged in learning activities across several contexts: (1) their classroom, (2) their homes, (3) field observations, and

(4) a “smartroom” (different from their classroom) where they engaged in carefully scripted interactions with an array of media and materials. We investigated an orchestrational framework that included the use of social tagging and metadata, as well as intelligent agents to support the enactment of collaborative inquiry scripts. The following sections will detail the design of the curriculum, the relevant technologies, and our enactment with two sections of a high school physics course.

Methods

Throughout the design process we employed a codesign methodology (Roschelle et al. 2006) working closely with a high school physics teacher to ensure that he was an active voice in the technology design and that the designed intervention “fits” his goals for the students and expectations for student learning. Because the research was situated within a real class (rather than a canned lab setting), a design-based research approach was implemented in order to respond to the multitude of variables present during its enactment (Wang and Hannafin 2005). Generally, design-based research does not attempt to validate a particular curriculum; rather it strives to advance a set of theories on learning that transcend the particulars in which they were enacted (Barab and Squire 2004). As such a major outcome of this research was the design of the curriculum and supporting technologies themselves. In order to evaluate the enacted design, we used a mixed methods approach in order to triangulate the data and get a more complete picture (Johnson et al. 2007; Mason 2006). Sources included pre- and post-interviews with students and the teacher, server logs, the user-contributed artifacts, and video and audio recordings during the culminating activity.

Physics Learning Across Contexts and Environments (PLACE)

In order to investigate the role that such technologies could play in supporting cross-context learning, we needed to develop a carefully designed curriculum that leveraged student-contributed content and included a meaningful role for intelligent agents and data mining. We work closely with the high school physics teacher to develop a curriculum that implemented KCI, including collaborative and collective forms of inquiry and adding a level of critical reflection to the teacher’s previous approach. Two main goals were identified by the teacher: First, he wanted to help students to recognize “physics in their everyday lives” and then bring this view of physics back into the traditional classroom setting. Second, he wanted to design some way for students to develop a coherent understanding of the underlying principles of the course, including the connections among those physics principles (i.e.,

Table 12.1 Grade 11 fundamental principles for kinematics, force and motion, and work, energy, and power

Vectors	Acceleration	Fnet = 0	Kinetic energy
Newton's First Law	Uniform motion	Fnet = constant (nonzero)	Potential energy
Newton's Second Law	Kinetic friction	Fnet = nonconstant	Conservation of energy
Newton's Third Law	Static friction		

to "see that all the principles are tied together"). We began by generating a list of fourteen principles (Table 12.1) that covered the first three units of the course: (1) kinematics, (2) forces and motion, and (3) work, energy, and power. Following the work of Chi, Feltovich, and Glasser (1981), we wondered if, by engaging students in principle-based classification of physics phenomena and problems, we could help them achieve a greater level of expertise.

In order to achieve these goals, we developed a script that engaged students in capturing examples of physics in the world around them (either through videos, pictures, or text), which they uploaded to the classroom database, "tagged" with any of the principles they felt to be applicable, with a written explanation for their choice of tags. The wider community of students was encouraged to respond to these user-contributed artifacts: debating tags or explanations, voting, and adding new tags – with the stated aim of developing consensus about each item. To support this process, we developed a micro-script that required students to complete three steps of (1) voting on existing tags and/or adding a new tag, (2) voting on the contributions of their peers, and (3) adding a reflection or rationale of their own. This was designed to ensure that students covered three key aspects (focus on the principles, reflecting on the work of their peers, and adding their own thinking). As part of the script, in order to ensure that all the principles were covered and to encourage students to become experts in particular principles, we assigned each student to an "expert group" in which they were assigned a subset of the principles (e.g., Newton's First Law, vectors, and potential energy) for which they were responsible to keep updated (i.e., to make sure all relevant items had been tagged and add a comment where they felt the principles had been wrongly tagged).

For each of the three units within the curriculum, students were tasked with uploading at least one example and to commenting on at least two of their peers' submissions (with a focus on their expert principles). At the end of each unit, the teacher selected some examples to discuss with the class and had the students look over examples that had been tagged with their principles, to add to their discussion. Students also uploaded results from their in-class laboratory experiments to the knowledge base, tagging their reports with principles and adding reflections on their methodologies – which other students were also free to critique. For homework, the teacher provided multiple-choice problems, which students solved using a script similar to the one used for their contributions: tag, answer, and reflect on the problem. All student contributions went into a collective knowledge base, which itself served as a basis for various further activities. For example, students were asked to develop "challenge homework problems" for their peers, using examples drawn from the knowledge base. Intelligent agents mined the knowledge base to retrieve principle-tagged problems during the smart classroom activity.

The teacher's role in the curriculum was also scripted, in the sense that he was expected to upload regular homework problems, review and assess student answers, and adjust class lessons accordingly. He was also expected to review student contributions, to find examples or interesting discourse for use during in-class discussions. Finally, his role was tightly scripted in the smartroom activity, where he had consequential roles of approving students when they had gotten to a certain point, providing feedback if he did not approve and leading whole class discussions.

S3 Supports for PLACE: Learning Across Contexts

To support student interactions at home, in their neighborhoods, and in the classroom, we needed a technology infrastructure that supported student activity, from completing homework problems, to uploading examples, to tagging and discussing peers' contributions. S3 supported our development of two complementary systems: *PLACE.Web* (Physics Learning Across Contexts and Environments), a collaborative social network, focused on the domain of physics, where students contribute content, engage with the work of their peers, and complete tasks assigned by the teacher, and *PLACE.neo*, a smartroom environment that orchestrated the activity, making use of the PLACE.Web content. Both PLACE.web and PLACE.neo employed elements of S3, including Rollcall, a user portal that provided each student a personal profile and nickname and lets them personalize their identity within the community. The use of Rollcall also allowed S3 intelligent agents to personalize the kinds of information visible to each student, the materials they were actively provided, and their group assignments in the culminating activity.

PLACE.web

The PLACE.web learning environment supported five different interaction spaces for the students: (1) the student status page, (2) the contribution upload page, (3) the user contribution discussion pages, (4) the assigned homework pages, (5) and the "associative web" – a semantically aggregated visualization of the entire community knowledge base.

- *The student status page* – This was the first page that students saw when logging into PLACE.web and was broken into several distinct information spaces to give the student a quick overview of their contributions and the state of the overall class activity (Fig. 12.3). The goal of this page orients students' personal place within the knowledge community and provides insight into possible avenues for

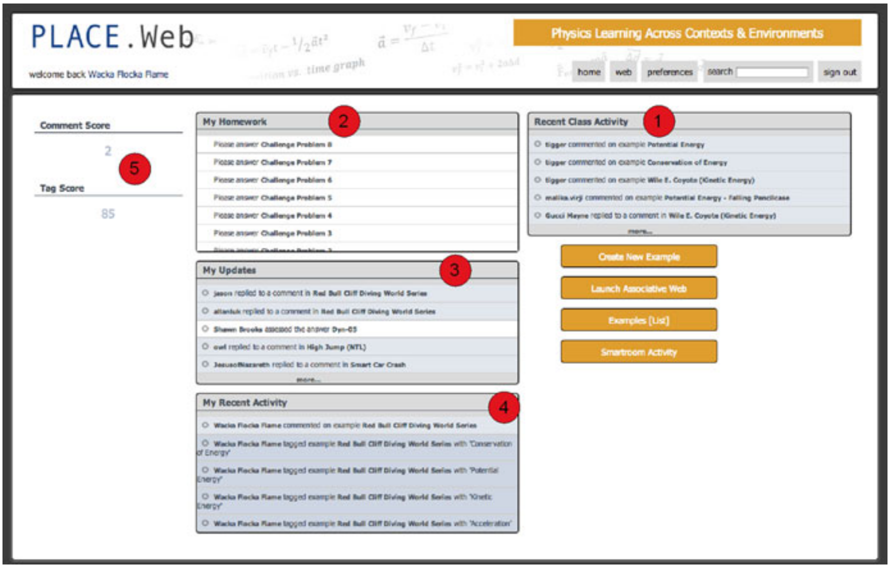

Fig. 12.3 The student status page had several informational streams to help students orient themselves within the knowledge community and manage their orchestrational load through (*1*) the recent class activity, (*2*) my homework, (*3*) my updates, (*4*) my recent activity, and (*5*) comment and tag scores

action when the teacher was not around to directly provide instruction or guidance. As such this page was one of the focal points of the informal student learning activities.

- The status page showed a news feed of the whole class' contributions ("Recent Class Activity"), giving the student a sense of the overall class activity and a means to jump to any particular artifact or comment they might have found interesting. The other feeds were personalized to the individual student: The "My Homework" feed showed students any tasks assigned to them by the teacher, which would automatically disappear once a student had completed the task; the "My Updates" feed showed the student any actions that other members of the community made on any of his or her contributions (e.g., commented on one of their examples, agreed or disagreed with one of their tags), providing students an active connection to the knowledge community and their place within it; the "My Recent Activity" feed tracked all the actions by the individual student, giving a means of tracking his or her own contributions to the community and quickly jumping to a space of interest (i.e., where he or she is involved in discourse). On the left side of the status page, each student saw a "Comment Score" and a "Tag Score," which tracked the total votes students had received from their peers for their contributions. This provided a means of motivating students to produce "high-level" contributions.

- *The contribution upload page* – This is where students uploaded their contributions (video, picture, or narrative) to the shared knowledge base. In addition to their uploaded media, as part of the scripted interactions, students were required to also assign tags and a rationale of their physics thinking to the contribution. The contribution upload page was designed to be as device agnostic as possible to allow students to upload and create content in a broad range of contexts (at home, in their neighborhoods, at school). We aimed to facilitate a level of mobile integration to PLACE.web, and students using Android devices could upload media directly from their device to PLACE.web, allowing them to capture physics "on the go." Students using iOS (iPhone, iPad) needed to first transfer their media to another computer before contributing it to the knowledge base.
- *The discussion pages* – The discussion pages (Fig. 12.4) in PLACE.web were designed to allow students to engage in discussion and debate and vote on the principles tagged to the contribution. These interactions took the form of threaded discussions, including aggregated votes for each of the principles. The contribution pages were used widely throughout the script, as students would engage in these spaces both at home and during scripted in-class sessions. These pages were also designed to be as device agnostic as possible so that students could access and contribute to them from any major browser, as well as from both Android and Apple devices.
- *The assigned homework pages* – These pages were teacher created and were centered on multiple-choice homework problems. The scripted interface was similar to that of contributions where students had to tag and provide a rationale

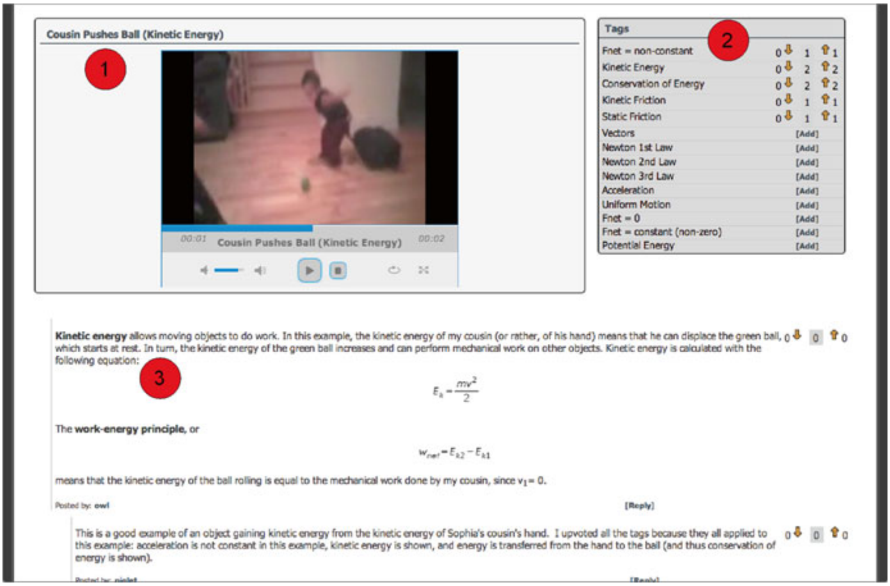

Fig. 12.4 An example of a contribution discussion page with (*1*) a student-uploaded video, (*2*) student-submitted principle tags and voting, and (*3*) threaded student discourse

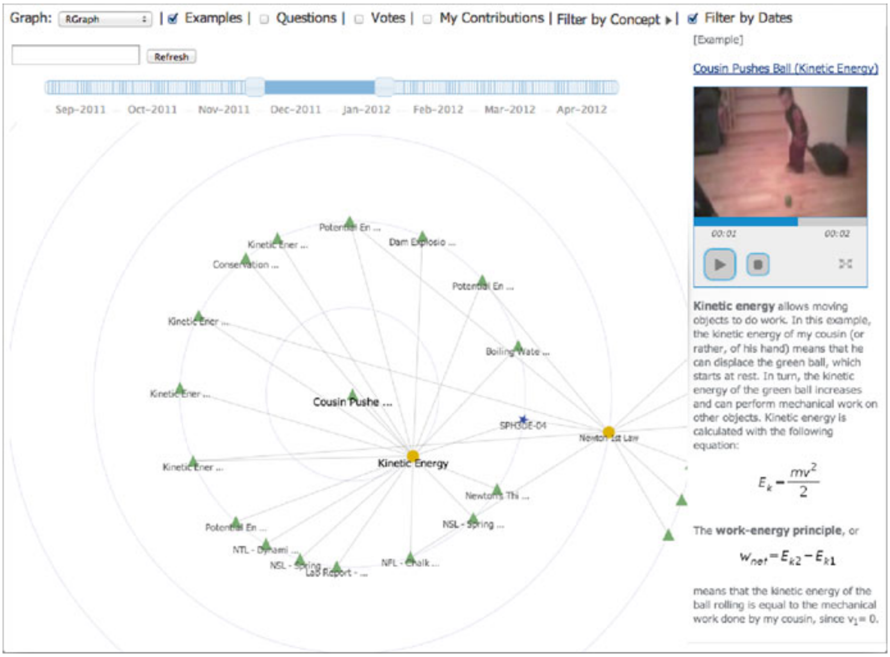

Fig. 12.5 Associative web, showing filtered view of the principles "kinetic energy" and "Newton's First Law," with examples from student contributions

in addition to their answer; however, with the homework problems the contributions of their peers were not shown to students. As with the discussion pages, students could access the pages from any major browser or mobile device.

- *The Associative Web* – The Associative Web (Fig. 12.5) was an interactive, filterable visualization that used the principle tag metadata to semantically connect all the contributions of the knowledge community. The Associative Web was used primarily during in-class activities in which students were tasked with finding examples that shared principles with their assigned expert group and when students were finding examples to scaffold the creation of their challenge problems. The teacher also used the Associative Web as a tool for in-class discussion by examining the clustering of student contributions as a way of finding similarities between seemingly disparate physics examples.

The teacher was also provided with tools to manage his orchestrational load, including a front status page that showed a similar set of feeds to those seen by the students. Akin to the student contribution upload page, the teacher was provided an authoring page that allowed him to create multiple-choice problems in a few short clicks. The teacher was also provided with two additional tools to give him insight into the class for adjusting the script based on understanding the class' emergent knowledge.

- *Built-in assessment* – The teacher was provided with a customized assessment tool on each contribution or homework page, allowing him to provide students with a mark (from 1 to 4) and personalized feedback. The assessment tool also allowed the teacher to write himself personal notes based on the student assessment to review toward adjusting upcoming lessons.
- *Individual student reports* – The teacher was provided a single page that provided detailed information on each student's activity on the site including links to his or her individual contributions and their total and average marks from his assessments of their work.

PLACE.neo: Leveraging Student-Contributed Materials and Tagging for New Learning Contexts

The goal of the culminating activity, following the KCI model, was for students to make use of their co-constructed knowledge base in the context of some final inquiry activity. Another important goal of this research was to investigate the technology infrastructure of S3, including some strong role for intelligent agents and real-time data mining. After many design discussions, we arrived at a challenging task that involved analyzing the physics of Hollywood movie clips, including setting up physics problems to test their validity. This culminating activity involved three micro-scripts that spanned home, a traditional class setting and a smart classroom, and relied heavily on S3 agents to coordinate the distribution of materials, roles, and tasks. At home, students were tasked with looking at a collection of the problems they had been assigned during the preceding 12-weeks (including their contributed challenge problems and new problems developed by the teacher), verifying their tagging of relevant physics principles, and adding equations that might be used to solve the problems. In class, students worked in small groups, using tablet computers to reach consensus on a refined "final set" of the tags and equations for each problem. These tagged problems, principles, and equations were thus processed by students from their collective knowledge base, to be used as a prepared set of materials within the final smart classroom script, where intelligent agents would access and distribute them.

Once entering the smart classroom, students were engaged in solving a series of ill-structured physics problems using Hollywood movie clips as the domain for their investigations (e.g., could Iron Man survive a fall to earth, as depicted in the movie?). Four videos were presented to the students, each at a distinct physical location within the room (Fig. 12.6). The students were engaged collectively, working as a whole group of 12–16, as well as collaboratively, in various small group configurations as commanded by the S3 intelligent agents. Agents made grouping decisions according to predefined scripting criteria, relating to the students' use of principles within an initial tagging activity and to the need to regroup students with peers they had not worked with yet. The smartroom script was broken up into four

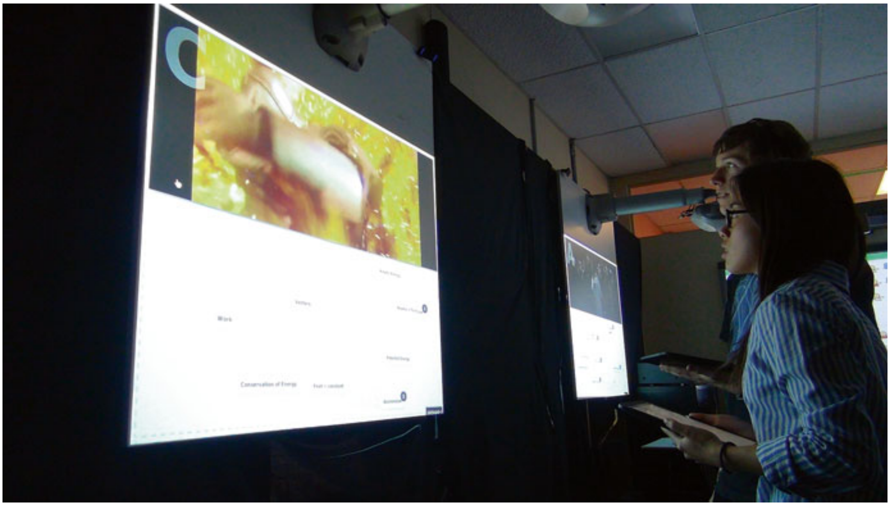

Fig. 12.6 Students engaging with the interactive displays and individual tablets in the smart classroom

different steps: (1) Principle Tagging, (2) Principle Negotiation and Problem Assignment, (3) Equation Assignment and Assumption and Variable Development, and (4) Solving and Recording. In each step students moved from one video to another, completing a set of collective and collaborative tasks that built upon the emerging knowledge base, using tablets and large-format interactive displays.

Technology Implementation of PLACE.neo

The script for the culminating activity relied heavily on the S3 agent framework in order to coordinate the complex distribution of materials, roles, and tasks. To scaffold the different contexts (at home, in class, in the smart classroom) and interactions (individual, cooperative, collaborative), we developed specific technology supports for each stage of the activity, in order to connect student activities with the knowledge base and achieve the overarching pedagogical goals of the script (i.e., solving the Hollywood video problems).

In order to facilitate the at-home portion of the script, and capitalize on the students' familiarity with the platform, we implemented this first stage using PLACE.web, adding a new icon to the existing student status page for students to access the activity. Drawing on the metadata that indicated each student's assigned content expertise, PLACE assigned each student a specific subset of the problems to tag with principles and equations. The use of the metadata allowed us to customize the problem sets seen by each student to ensure that every problem was "covered" by all fourteen principles.

During the in-class portion of the culminating activity, we developed a context-specific tablet application that connected students to their peers in real time, using the aggregated products of the previous at-home stage. Once again, we used the students' expertise metadata to group them, sending each student's group assignments to his or her tablet. The goal of this activity was for students to achieve consensus about the principles and equations that had been assigned to each problem in the corpus. The group would be assigned one of the problems, with each student seeing the problem and its various tags on his or her tablet, and asked to agree or disagree. In order to ensure consensus was achieved, we employed a *Consensus Agent,* which required all students within a group to have the same choices on their tablets before moving to the next task. Students could see the work of their group members in real time, reflected on their own tablets, which facilitated face-to-face discussions. We distributed all the problems to the groups using an S3 *Bucket Agent,* where a group was provided with a new problem once it had finished its existing one, and when all problems were gone (i.e., the "bucket" of problems was empty), they received a "please wait" message. In this way, groups who worked faster or who had received easier problems were given more problems, such that a large number of problems were addressed in an efficient, distributed fashion.

For the smart classroom stage of the script, we developed a script, which took advantage of the physical and collaborative affordances of the smart classroom, including large projected displays accompanying each video station and individual tablet computers to support students as they performed activities. The students' tablets coordinated all activities, populated by intelligent agents that drew content from the products of the in-class activity. Students worked in small groups, with the products of their individual tablet interactions aggregated and broadcast to the large group display, which then led to further collaborative knowledge building tasks. S3 agents queried metadata to provide students with context-specific tasks and materials, drawn from the corpus of student-contributed and student-tagged materials from earlier activities. The smart classroom script consisted of 4 steps (see Fig. 12.8), described below.

In step one, each student received a set of three or four principles (i.e., out of the 14) on their tablet, determined by querying that student's prior expertise groups. The students were asked to go to one video at a time and to "swipe" any of their four principles that they found relevant to the video onto the large display at that station. After four 2-min intervals, all students had tagged each of the four videos with any of the principles that were relevant. Because each principle had been assigned to at least two students, there were multiple instances of the principles on the boards (see Fig. 12.9).

In step two, students were assigned, by an S3 *Student Sorting Agent*, to one of the video boards, according to where they had swiped the most principle tags (while still evenly distributing the students around the room). The student tablet provided the ID of the video to which he or she was assigned (e.g., "A," "B," "C," or "D") and walked over to that video station. Once all students had arrived at their assigned stations, the teacher "advanced" the script using his tablet, and students received their task: They first negotiated, with the aid of a *Consensus Agent*, the

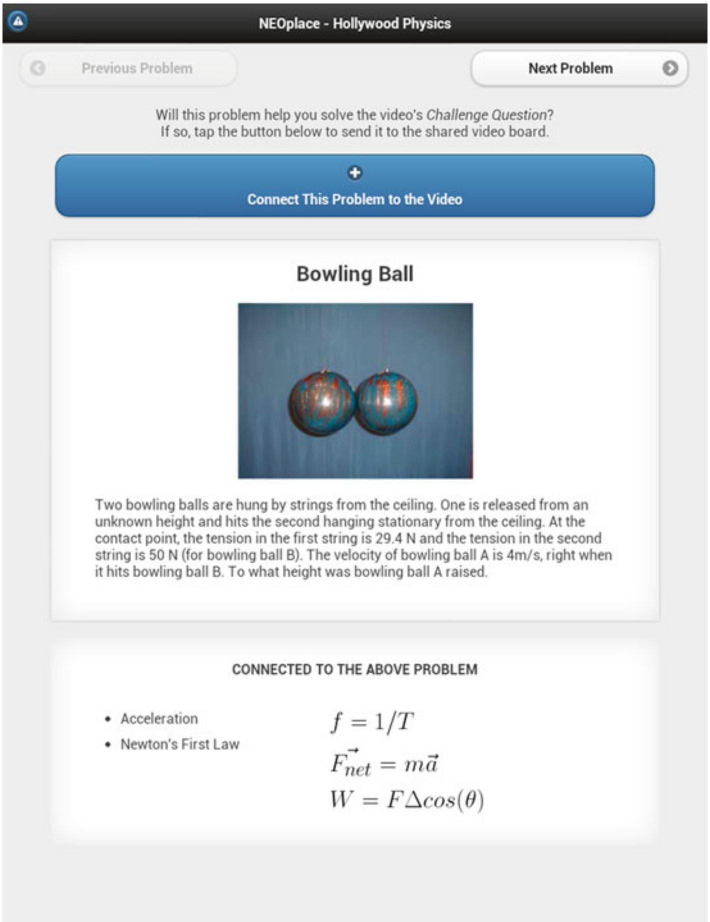

Fig. 12.7 Individual student tablet screen from the smart classroom activity's problem assignment task (step 2)

final principles for their video. Then, another S3 Bucket Agent retrieved the physics problems that had been tagged with those principles in the previous (in-class) activities and distributed them to the individual students within the group, who made simple "yes or no" decisions about whether the problem might be an interesting model for how to set up the video, for solving in problem form (Fig. 12.7 above). Unlike the *Bucket Agent* in the in-class activity (whose goal was to get students through the task as efficiently as possible), this agent aimed to get all the students in a group involved in idea promotion and negotiation. As such, each member in the group received an equal but unique set of items that were semantically connected to their video by the S3 agent. As part of the script each student had to promote at least one problem to the negotiation board from their set (Fig. 12.10), encouraging each student to take an active role in setting up the

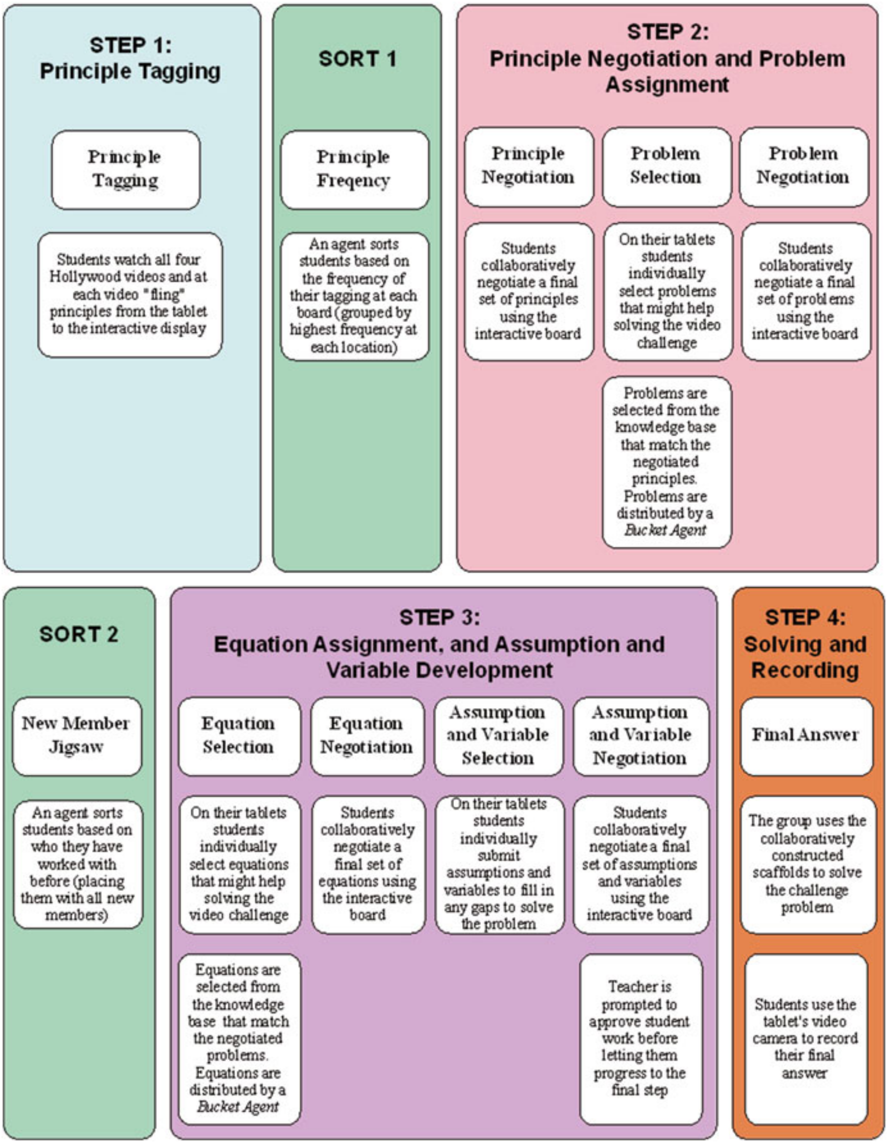

Fig. 12.8 The smart classroom Hollywood physics script involved four distinct steps

problem. Additionally the movement between the "private" space of the tablet and the public and collaborative space on the interactive walls aimed to have students work in multimodal contexts within the activity.

In step three, a *Student Sorting Agent* reassigned students to new video stations, based on a criterion for grouping students who had not worked together in any

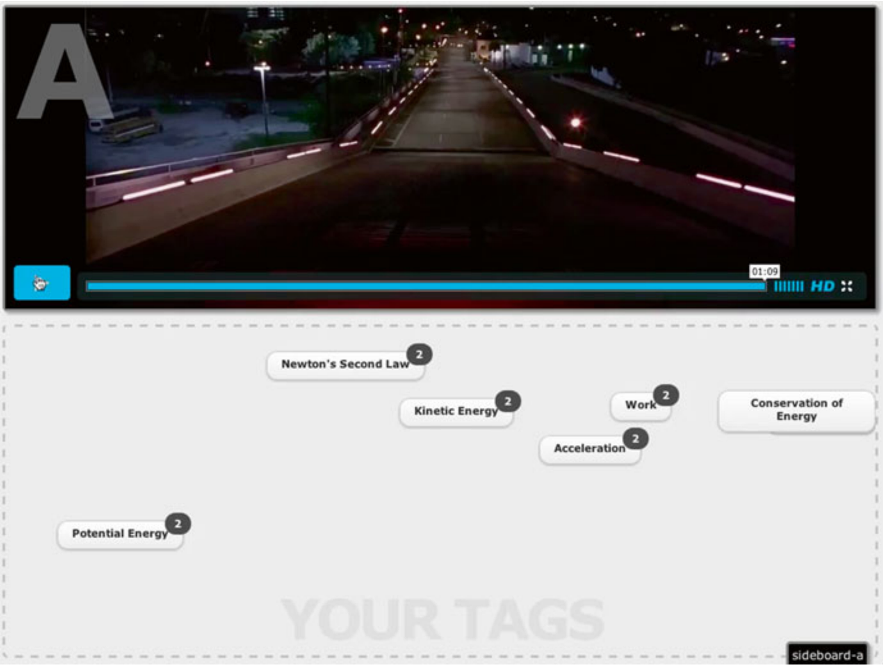

Fig. 12.9 Interactive board during step 1 – the principle tagging phase. The numbers indicate how many times the video was tagged with that principle (e.g., two students tagged the video with "Work")

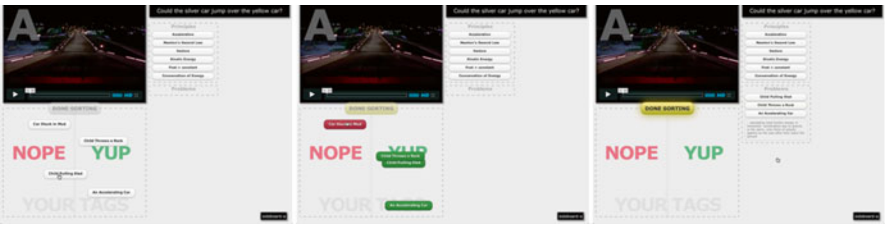

Fig. 12.10 Shows the three phases of the Problem Selection task (step 2), where students (*1*) submit problems from their tablets to the interactive board, (*2*) negotiate which problems to keep or discard by dragging them to the "Yep" or "Nope" zone of the negotiation space, and (*3*) after negotiation the final set appears on the *right*

previous step. A *Bucket Agent*, similar to the one employed in step two, distributed the problems to students at each board and showed them the equations connected to the problem during the in-class portion of the script. Students promoted those equations they felt might help in solving the challenge question to the shared display and negotiated a "final set" which was again facilitated by the Consensus Agent. Group members then individually came up with assumptions and variables to fill in any information "gaps" and engaged in the negotiation and consensus script to produce a final set. Unlike with the other negotiation and consensus tasks, when a group submitted a final set of assumptions and variables, the teacher was alerted on his orchestration tablet to review students' work and either approve it or to send them back to refine their submission.

In step four, the final step, student groups used the collaboratively constructed scaffolds on the interactive whiteboards for support and with pen and paper solved their challenge problem and recorded their final answer as a video narrative using the tablet's built-in video camera.

A critical part of this design was that in order to make these complex orchestrations occur and draw materials that had been tagged during the previous in-class stage, the S3 agents needed to be able to respond to the emergent conditions in the class. The S3 agents could not know what tags the students would choose in step one (which would determine the problems selected for step 2 or the problems selected from step 2 for the equations for step 3), and therefore had to be developed as adaptive scaffolds responding to the real-time products of the class' knowledge construction.

Enactment of the PLACE Script

PLACE was implemented with 2 sections of grade 11 physics ($n=22$, $n=22$) in an urban high school. Over the 12-week curriculum, the students were actively involved in the development of artifacts and in the discussion around the physics principles connected to them. Students regularly uploaded examples to the database and engaged in discussion around their physics principles. Below we discuss students' contributions across different contexts and their subsequent reuse in class and during the smart classroom activity.

Student-Contributed Content

In total 169 student examples were created, and 635 total student discussion notes were contributed around those examples. Students also attached 1,066 principle tags to the contributed examples and cast 2,641 votes on those tags. Although the designed script required students to upload at least one example in each of the three units (3 contributions in total), students on average submitted 3.84 examples to the knowledge base (excluding the challenge problems), which seems to point to active community engagement.

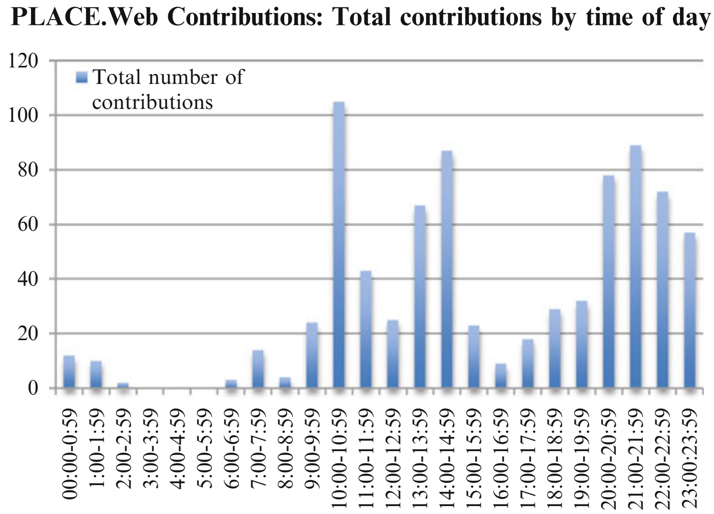

Fig. 12.11 Graph shows the total number of student contributions to PLACE.web distributed by time of day

During the enactment of the script, students were actively engaged in school, at home, and in their neighborhoods. An examination of the time of day at which students contributed to the knowledge base shows that uploads or comments were made within PLACE at nearly every point of the day (the only exception being between 3 am and 6 am, see Fig. 12.11). This highlights the ability of PLACE.web to seamlessly connect students within their overall community whenever they felt the desire to take part, with 46.58 % of contributions taking place during school hours (9 am–4 pm) and 53.42 % of the contributions taking place outside of school hours (4 pm–9 am). Interestingly, nearly 2 % of the overall interactions took place during students' lunchtime (12:30 pm–1:15 am), which indicates both the interest and ability to access PLACE outside of traditional in-class hours, even while still in the formal school setting. The teacher involved in the study noted that several times students came up to him in the hall with their mobile devices, to bring up a homework question or a peer's example, and asked his thoughts about their response. He stated that he was amazed not only at their interest but also their ability to have the content "at their fingertips."

An examination of the types of student-contributed content also highlights the seamless nature of PLACE. Student-contributed examples included videos of friends at a track meet, a subway arriving at a station, a student pushing a friend into a pool, a student's young cousin rolling a ball in their house, and a pair of students rolling two different-sized objects down the school's hallway. All of these examples point not only to the ability of PLACE to capture moments of student insight but also, perhaps more critically, that the curriculum, and PLACE as a support for the curriculum, got the students actively seeking out, capturing, and questioning physics in their everyday lives.

Using Peers' Contributions: The Challenge Problem Script

Working collaboratively in groups of three to four in the classroom, students were tasked to create "challenge problems" that would be solved by their peers, drawing from the wider knowledge base of peer-contributed examples. This script was seen to engage students and leverage their collective knowledge base, leading to the development of further materials for peer engagement and investigation. In total, 13 challenge problems were developed by students, each of which referred to, on average, 2.23 examples from the knowledge base. The Associative Web was employed as an in-class tool to help students find examples that matched their expertise groups and supported their creation of a challenge problem. In post-activity questionnaires, students indicated that they found the Associative Web very useful for filtering the overall knowledge base and to find artifacts that matched their individual search criteria, noting that "*the examples about each concept were easily identified and similar examples were grouped together,*" and "*the associative web made it clear what examples are related to our concepts, because you could see what example was related to more than one of the concepts, and it's easy to browse through multiple areas.*"

Culminating Activity: Scripting and Orchestration Across Contexts

During the culminating smart classroom activity, students were able to access, contribute to, and use the knowledge base at home, in class, and in the smart classroom. This activity was an important test of the capabilities of S3 to support seamless orchestration of learning activities, and the use of intelligent agents was central to our success. The next three sections address how S3 agents supported learning in each of the three contexts.

Agent Orchestration of the At-Home Activity

In the at-home portion of the culminating activity, students were scaffolded in answering a subset of the homework problems, depending on what "expertise groups" they had been assigned to in previous units. S3 agents were employed to ensure that each problem ($n = 30$) was received by students who represented all fourteen principles. This was successfully achieved, ensuring that every problem in the corpus was reviewed by the knowledge community in terms of every principle.

Agent Orchestration of the In-Class Activity

During the in-class portion of the activity, S3 agents successfully grouped students and facilitated their consensus building on all of the homework problems. Of particular interest within the in-class activity was the effectiveness of the *Bucket Agent*

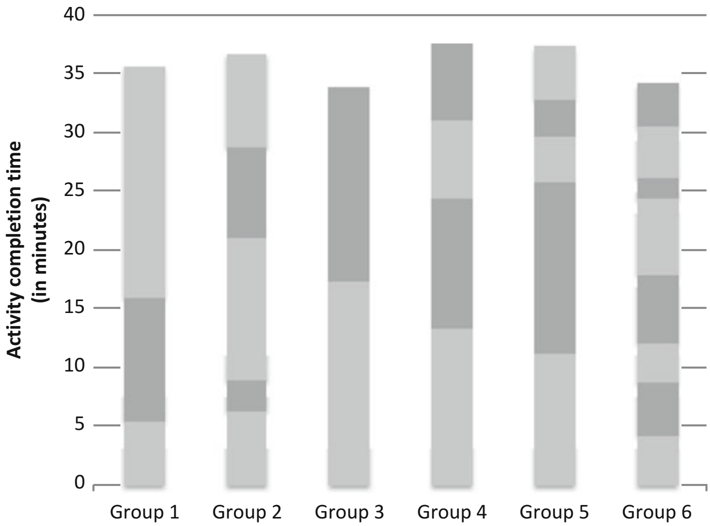

Fig. 12.12 *Shaded bars* show the number of problems sent to each group by the *Bucket Agent* and how long the students spent on each problem. For example, group 3 took a long time on both of its problems, so they only received 2

in orchestrating the real-time distribution of the problems to the individual groups. Given the time constraints in the classroom – only 60 min, which included all the kids arriving in class, taking their seats, and the researchers distributing the tablets and explaining the activity *before* starting – it was imperative that the problems were distributed as efficiently as possible. The *Bucket Agent* regulated the distribution of problems in such a way that every group completed their assigned problems in less than 40 min and within 3 min of each other (Fig. 12.12), minimizing the variance between time on task for groups.

Agent Orchestration of the Smart Classroom Activity

Within the smart classroom portion of the culminating activity, the S3 agents successfully responded to emergent properties of student interactions to supply them with semantically relevant artifacts, drawn from the in-class activity. During step 2 of the smartroom activity (the "Problem Assignment" step), students were given problems, drawn by agents from the knowledge base, whose principles matched those that had been assigned to their video clip. The S3 agents connected, on average, 23 problems to each video, of which students agreed (voted "yes") to an average of 3.4 problems, which were negotiated down (during the whiteboard consensus phase) to an average of 2.6 problems. During step 3 ("Equation Assignment"), S3 agents were able to draw, from the knowledge base, the equations that had been assigned to those problems, to serve as resources for students in setting up their solutions to the video clip challenges. From these agent-filtered equations, students

Table 12.2 Student tagging frequencies and sorting agent assigned boards for step two and step three

Students	# of tags by student Board A	# of tags by student Board B	# of tags by student Board C	# of tags by student Board D	First sort: sent to board	Second sort: sent to board	Sorted to new board?	Sorted with new team members?
Alice	4	3	3	4	A	B	Y	Y
Pearl	3	0	3	2	A	C	Y	Y
Jason	4	3	4	4	B	C	Y	Y
Rob	0	3	3	1	B	D	Y	Y
Desi	3	2	3	0	C	D	Y	Y
Raffi	0	2	2	2	C	A	Y	Y
Becky	2	2	3	3	D	A	Y	Y
Sun	2	2	0	2	D	B	Y	Y

recommended an average of 4.9 equations, which were negotiated down to an average of 4.3 equations, during the whiteboard negotiation phase.

In between steps of the smart classroom activity, the *Student Sorting* Agent was able to successfully sort students into groups based on the number of principles they had signed to each video (step 2) and ensuring they were working with new groupmates (step 3). We approached this challenge by having the agent build a table of student interactions (similar to Table 12.2, above), which was used in a cascading fashion to assign one student to board A based on their frequency of principles, then one to boards B, C, and D in order, before repeating this process until all students were sorted. Jason was assigned to board B and not A, C, or D because the agent had already placed Alice at board A, and Jason had the most tags when the agent went looking for a board B student (i.e., for the second assignment by the agent's algorithm).

Solving the Hollywood Physics Problems

In the final step of the smart classroom activity, it is important to note that students were successful in setting up and solving the Hollywood film clips, using the assumptions and equations that had been generated from previous steps. Every group succeeded, in the time allowed, in generating a written solution to the problem and creating a short video where they explained their solution.

By looking at the final state of the collaboratively built knowledge on the interactive whiteboards and comparing it to the elements (such as the assumptions and variables and equations) used by the students in solving the problem (Fig. 12.13), we can begin to see how the interactive board was useful for scaffolding the students' problem solving. The exit interviews with students supported the visual evidence of the value of the boards, the user-contributed content in this scaffolding

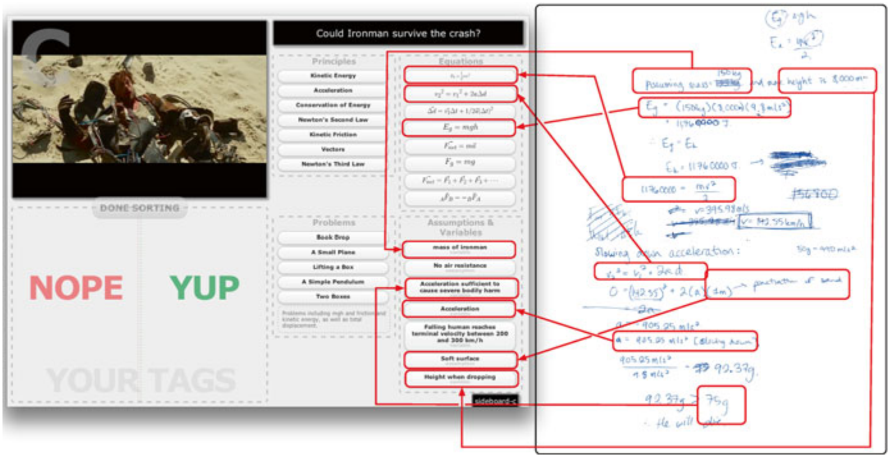

Fig. 12.13 This shows a group's final worksheet for solving their challenge problem. The *red* boxes highlight which elements (i.e., equations, variables, and assumptions) on the worksheet correspond to the codeveloped elements from their zone's interactive display (Color figure online)

process as students noted that "*having the tags and the equations gave [them] a general idea of what the problem related to, so [they] knew the kinds of information to draw from, so it narrowed [their] scope a lot.*"

Evaluating the PLACE Enactment: Did We Support a Knowledge Community Across Contexts?

PLACE was designed as a 12-week curriculum that enabled students to spontaneously and seamlessly connect with an evolving knowledge base across a variety of contexts through carefully scripted interactions. This required that students would be able to contribute and access content when the desire or need arose, but also that such interactions with the knowledge base would be conducted within the course of carefully scripted activities that included various forms of technology scaffolding.

PLACE has been instrumental in supporting our own understandings about how to design and enact such responsive and adaptive curriculum within a well-defined model for learning (KCI). An effective means of evaluating the overall design of PLACE is to examine its ability to achieve its codesigned curricular goals within the context of the KCI model. Thus, we discuss PLACE's enactment in terms of the KCI model below and quote excerpts from both student and teacher exit interviews to support our evaluation.

Within PLACE, students were able to collectively develop the knowledge base through their contributions of examples of physics in their everyday lives (by capturing examples both in their neighborhoods and from the Internet) and to discuss and refine these ideas in parallel. PLACE seamlessly facilitated student engagement with the knowledge base across four very distinct contexts (at home, in their neighborhoods, in class, in the smart classroom), and its design adapted to both students' informational (e.g., providing students with filterable aggregated views of the knowledge base with the Associative Web) and pedagogical (e.g., drawing relevant material from the knowledge base to scaffold student inquiry in the smart classroom) needs.

The evolving knowledge base was not a stand-alone product. Rather, it was used as a resource for both the development of peer challenge problems and to scaffold student inquiry during the culminating smart classroom activity. All of the interactions within PLACE were directly connected to the domain of physics and were further indexed to specific areas of inquiry (the codeveloped principle tags). Student development and the use of the knowledge base were achieved through carefully scripted activities that were sensitive to the context (where the activity took place), the types of interactions (individual, parallel, cooperative, collective) taking place, and a diverse range of media (including laptops, tablets, and interactive large-format displays).

Sarah: *I think that really made us think and made us also realize that there really is physics in everything, because once we got talking with friends to figure out where can I find Newton's First Law, or Second Law, or Third Law, it was really in literally every aspect of our lives… I had the opportunity to talk to students who have analyzed what they can see around them and examples of those laws that they learned in class; talking to them really helped… even working with people who worked on the same [principles] as me, they would have something, examples, that I would have never thought of.*

From the outset, PLACE was designed to address two targeted science learning goals: (1) facilitating students' investigation of science in situations outside of traditional classroom settings, to help them see "science in their everyday lives," and (2) to help students develop a deeper understanding of fourteen "fundamental" principles of their physics curriculum as determined by their teacher. The macro-scripts within PLACE were carefully designed to have students focus on these principles during artifact creation and debate, and PLACE itself has specific prompts and software checks to ensure that these facets of the script were completed by the students. The scripting of student roles (expert categories) and the peer-contributed examples they were expected to review (as part of the in-class review micro-script) ensured that students interacted with a wide cross section of the knowledge base, toward building a comprehensive understanding of the overall domain.

Teacher: *The tagging part of it enables them to share the same language, and I'm quite sure that five years from now if we were to study these kids, they would remember more about Newton's Laws and things like that than a regularly educated kid here at [the school]. I'm kind of sure because they had to tag all those things; those concepts, conservation of energy, and so on would be more in their brains I think – which is kind of neat because* *the sort of stuff I think they should take away with them is the knowledge of those tags and not so much problem solving subbing into equation stuff. But that conceptual learning would be great if kept forever.*

Steph: *[In] PLACE, I remember what I liked personally, and I know this from my own experience, is taking all the things we did and putting them together at the end… where we took all of it in the smart classroom at the end and put it all together, all the different pieces, for me that was the most interesting part.*

In PLACE the teacher's role was clearly specified, within both the macro- and micro-scripts. As described above, within the broader macro-script the teacher was actively engaged in the development of regular homework activities for the students and in monitoring student contributions to the knowledge base toward providing feedback and formal assessment (including grading student contributions and homework using the teacher feedback tools). In the micro-scripting of activities, the teacher was able to look into the class' "state of knowledge" (by reading the student-generated discussion) in order to adjust upcoming class lectures and to engage students in in-class discussion around student-generated artifacts or particular homework questions. During the culminating activity, the teacher used specialized tools to orchestrate the flow of activities in real time.

Teacher: *It was like: Wow I didn't have to explain that before – well that was because I didn't know kids were thinking or confusing that particular thing before.*

Evaluating the S3 Software Agents Within PLACE

A significant outcome of this research was the advancement of the S3 technology infrastructure, which supports knowledge communities across a diversity of contexts and scripted interactions. Central to the ability of S3 to make these interactions possible was the careful design of the intelligent software agents that acted upon the emergent metadata of the knowledge community. This paper advances the notion of three general classes of agents that leverage this metadata toward facilitating both real-time (micro-) and longer duration (macro-) scripted activities: Content Agents, Activity Sequencing Agents, and Grouping Agents. Below we evaluate our implementation of these agents within the PLACE curriculum enactment.

Content Agents

During their creation and debate of physics examples, the personal student tracking agents effectively encouraged students to monitor their own contributions and the growth of ideas of the community. An examination of the server logs and individual students' interactions with artifacts showed that students often did return to their previous contributions after other classmates had acted upon them, indicating a sense of ownership and engagement with their contributions to the knowledge base. The status page was a catalyst for this sustained involvement, by tracking and displaying an individual's contributions and changes to these contributions, PLACE was able to give students a sense of belonging to the community and of the continued growth of ideas.

Pearl: *It was good knowing there was just one place you could go and then finding all your stuff there and just posting your questions. You could see what everyone else was doing; it was easy to evaluate my progress over the year.*

Within the culminating smart classroom activity, agents effectively captured and responded to the emergent metadata of student interactions (i.e., negotiated principle tags and problems), their location within the room (e.g., board A), and other students in the room who shared their location toward distributing script- and context-dependent materials. For example, the *Bucket Agent* distributed materials to facilitate whole group involvement in the task.

Tim: *Well [outside the smart classroom] it would be on a computer screen or something like that, so you'd be like "do this," but we wouldn't be all interacting with it; here I think everyone could all interact with it which was what made a difference.*

Similarly, during the in-class portion of the culminating activity, a *Bucket Agent* used a different pedagogical goal (that of getting through all the material in a time-efficient way), to monitor individual groups and distribute materials across the entire class in a way that allowed the script to be completed within the tight time constraints of a single class period (even with all of the distractions and delays of a "normal" class).

Activity Sequencing Agents

In PLACE, the Activity Sequencing Agents played several major roles in the enactment of the culminating activity. First, the *Consensus Agents* helped students to reach consensus on ideas before moving them to the next task thereby promoting the open discussion of ideas

Sarah: *There was a lot of sharing and applying knowledge, because you had to explain to other people why [a principle or an equation] would apply, and it was kind of recapping your knowledge and also persuading others, expressing your opinion, everything that we did together.*

The *Student Progress Agents* tracked individual, small group, and whole class progression, giving both students and teachers insight into the state of the class within the activity toward reducing orchestrational load. Such agents continuously refreshed the ambient display to show students where they were within the script, when they had completed a phase in the activity, and when the time for an activity had run out. These same agents also alerted the teacher when all the groups had completed a step (on his orchestration tablet), before activating the next step in the script. When the teacher activated the next step on his tablet, the students' individual tablets were instantly updated to reflect the new step in the activity and their own specific roles and locations.

Sarah: *It was a good way to pace everybody and make sure that everyone was going at the same pace.*

Grouping Agents

Within PLACE, the *Grouping Agents* played a central role in the orchestration of the smart classroom activity. The ability for these agents to group students based on specific predefined pedagogical configurations where the students who would fit their conditions could not be known a priori was an exciting outcome of the smart classroom implementation. The grouping and movement of students is a complicated and time-consuming task in any classroom, and being able to not only automate it but to also include processing of emergent patterns (something that would be impossible for a human in real time) provided critical support for managing the class' orchestrational load. In PLACE we successfully demonstrated two such agents (sorting students based on tagging frequency and a modified "jigsaw") which hold promise for more complex ones in future iterations.

Teacher: *It was such a sort of shifting paradigm kind of lesson, with the pacing and, I don't know, just the kinetics and the motion in the room and kids moving around was a lot to follow, [but] I didn't need to worry about it, it was just taken care of by the various technologies.*

Jen: *Well normally the teacher would just say ok and now your next group is this, and they would be the one who would say ok now your time is up and things like that. But with the board it was like ok, this is where we have to go, and that's how much time we have left, so we didn't really need the teacher for that any more… he could just focus more on going around and talking to the groups.*

Transitions Across Contexts: Factors and Design Principles

One outcome of this research is our ability to reflect on how the curricular design supported not only productive interaction *within* different contexts but also the transitions *between* these contexts. Below we describe several design principles for cross-context learning that arose from this intervention. We do not propose that the principles described below are the only possible ones for supporting cross-context learning nor do we suppose that our uses of these principles are the only ones possible; rather given the relatively new domain of this research, we offer our findings as a starting point for other researchers who wish to enact similar designs. We discuss these principles in relation to three transitions that were central to the successful enactment of PLACE, the goals for using materials from previous contexts, the strategy we adopted the script design, and the use of intelligent agents, data structures (e.g., structured and semantic metadata), and data mining.

Visualizations of Community Knowledge

The first transition that we had to consider was between the **individually collected examples** and **collaborative online inquiry activities**. We wanted student-contributed content, rather than materials found in textbooks or other professionally curated materials, to play a meaningful role in the class' inquiry. To this end we designed scripts that specifically required students to draw from the collaboratively constructed knowledge base (e.g., the in-class Challenge Problem Creation script). Our main challenge was finding ways for groups to meaningfully search the large repository of student artifacts to find materials that fit their specific needs. It was in response to this challenge that we build the Associate Web. The associative web was able to mine artifacts from the knowledge base based on their student-assigned tags and present them in a way that was both useful and meaningful for the given context.

We also wanted students at home to see how in-class activities, such as scripted "peer feedback" activities, affected their own contributions to the knowledge base. This was the impetus for the aggregated news feeds, which leveraged system-generated metadata about individual students (e.g., which artifacts they had contributed to or worked on). These different aggregated and filterable views served as a bridge for students to orient themselves within the larger knowledge community when on their own at home.

Design Principle: *Aggregated visualizations of the community knowledge base can play a meaningful role in bridging contexts, but must present the information in ways that are relevant to the context and scripted activity.*

Data Structures and Semantic Metadata Supports

The second transition concerned the movement of materials and student roles between the **at-home stage** (on PLACE.web) and the **in-class stage** (using PLACE.neo tablet apps) of the culminating activity. We needed the small groups to review the work of the individual students and to gain consensus on their assignment of principle tags and equations. In order to do this we needed the system to collect all the individual responses from the at-home stage and aggregate them in ways that allowed students to collaboratively discuss and debate them. Because the underlying metadata was clearly semantically defined (e.g., using metadata structures such as "problems," "principles," "equations"), we were able to easily create views that supported the desired scripted interactions.

These same semantic metadata structures also played a significant role in transitioning the **in-class** artifacts to the **smart classroom**. In the smart classroom, PLACE.neo was able to connect the negotiated tags assigned to a video wall (during step 2, see Fig. 12.8 above), to those attributed to the artifacts from **in-class stage**, to present students with items from the knowledge base that shared the same tags as the video. The ability to leverage the semantic metadata generated in each context allows information to not only move seamlessly between contexts but to also be aggregated in new ways as the knowledge base grows and becomes more interrelated.

Design Principle: *Data structures should be designed to facilitate the organization of student materials for use across different contexts.*

The Orchestrational Role of Intelligent Software Agents

Within the **smart classroom context,** we wanted students to be able to use the materials generated during the **in-class stage** of the script as scaffolds for their problem solving. For this design we knew that the system could not know *a priori* which items would be need by which groups during the activity. In response we needed to develop agents that could draw from the database artifacts that were semantically connected to the students' inquiry and distribute those artifacts evenly to all the group members. Requiring a teacher (or the students) to be aware of every item in the database and their potential connection to the evolving products or real-time inquiry requires a prohibitive level of orchestrational load on participants.

Similarly, during the **in-class stage** we needed to distribute the aggregates of the problems completed during the **at-home stage** (described above). The goal of this activity was not to make sure *every* group saw the same number of problems; rather it was to ensure all the problems we have seen *once* within the confines of a 60-min class. As described above, each time a group gained consensus on one of the aggregated art-home problems, the *Bucket Agent* was able to send another from the set to the group. The ability to quickly assess the state of the activity and draw the required materials from another context in pursuit of the scripted goals provides another layer of adaptive orchestrational support.

This study shows the potential for intelligent software agents to assess complex and changing orchestrational factors such as a student's location (both within and outside the classroom), whether they are working individually or collaboratively; their place within the script; and their past actions to connect them with required materials from the knowledge base. Although our research only engaged these particular agents in two specific spaces (in class and in a smart classroom), the results show promise supporting learners across a wide range of contexts depending on their emergent needs within complex pedagogical scripts.

Design Principle: *Intelligent software agents can help orchestrate class activities that require the retrieval of materials from other contexts based on real-time search conditions or emergent class patterns.*

Conclusions and Future Directions

This study addresses the challenge of developing innovative learning environments for students that blend rich inquiry with the world around them and well-defined pedagogical and curricular goals. We develop technologies that allow students to seamlessly take part in a community whether they are at home, in class, or out playing with friends. How do we transform and aggregate potentially large sets of user-generated data in ways that make sense to students in terms of their progressive knowledge work? How do we script the micro-activities across these contexts to facilitate our longer-tail curricular goals? And what role can intelligent agents play to aid in facilitating the orchestration of these increasingly complex scripts? By designing and enacting PLACE, we have begun to understand the role that agents can play within these systems by providing students with timely insight into their place within the community, suggestions for next steps, the delivery of timely resources, and the grouping and assignment of roles in response to emergent patterns within the class.

As we progress in our investigations, there will be new opportunities for agents to leverage the semantic metadata of the community to create knowledge awareness both for the individual students by more directly connecting them with the relevant products of their peers and the community by producing unforeseen "rise above" trends for further class investigations. These agents have the potential to connect both the long-term investigations of students through persistent portals such as PLACE.web and by making decisions in real-time based on complex student patterns and emergent data that would be impossible to do by hand as in PLACE.neo. As we move forward in these designs, we must be mindful of the role of the teacher within such complex curricula and not relegate them to a role of passive observer or vague instructions to be a "guide on the side." Instead, we must include carefully designed orchestrational supports that empower teachers as active facilitators and role players in the knowledge community.

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Part III
Pedagogies and Application Domains of Seamless Learning

Chapter 13
Mobile Seamless Learning and Its Pedagogy

Howard Nicholas and Wan Ng

Abstract Mobile connectivity enables learners to make connections across different contexts and across different learning experiences in the different contexts. This requires both ubiquity and seamlessness. However, both concepts need to be framed in relationship to a clearer understanding of what learning should entail. We will analyse relationships between ubiquity, seamlessness and learning in order to develop a view of seamless learning that addresses three issues: context, nature of learning and technological constellation. Building on the relationships that we propose between these three issues, we will discuss ways of framing pedagogy so that mobile seamless learning occurs.

Introduction

In this chapter, we will argue that seamless learning is a term with intimate but under-specified connections with both ubiquity and seamlessness. We will explore the definitions of all three terms, ubiquity, seamlessness and learning, to gain an understanding of how they relate to each other. We will show that the nature of learning in "seamless learning" is under-specified. Having specified how "learning" should be understood, we will identify the crucial aspects of both ubiquity and seamlessness that need to be invoked for seamless learning to become both a desirable and a viable practice.

In conceptualising seamless learning we need to consider and distinguish three connected elements: (1) the resources available – including distinctions and relations between digital and physical environments, (2) transitions and connections between those resources and (3) the purposes of using them – with learning understood as a specific purpose with specific characteristics.

The relationships between these different elements are unclear at best. The elements are frequently referred to using either or both of the terms "ubiquitous" and "seamless" together with an often unclear blurring between computing and learning.

H. Nicholas (✉)
Faculty of Education, La Trobe University, Melbourne, VIC, Australia
e-mail: h.nicholas@latrobe.edu.au

W. Ng
Faculty of Education, University of New South Wales, Sydney, NSW, Australia

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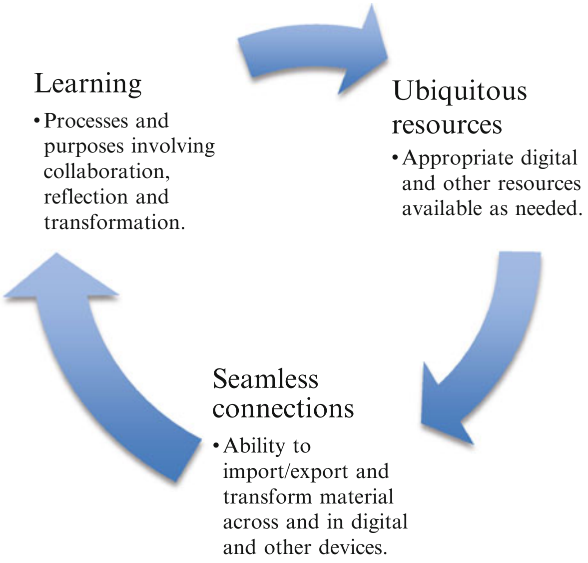
Fig. 13.1 The key elements



Concepts such as ubiquitous or seamless computing seem to meld into ubiquitous or seamless learning without consideration of the distinctions between technologies and learning purposes. Cope and Kalantzis (2013) refer to the work of Twidale (2009) in describing ubiquitous learning as "a riff on the idea of 'ubiquitous computing'". Both the elements and their relationships need clarification. We will argue that the elements are distinct even though for the purposes of powerful learning they need to exist in mutually shaping relationships (see Fig. 13.1).

It is particularly important to consider the roles of purpose in distinguishing, on the one hand, the enabling elements of resources, transitions and connections from, on the other hand, learning as the purposeful deployment of those elements. In doing this, we will observe that there are close relationships between ubiquity and seamlessness but that there is a need to be much more explicit about how we understand "learning" and its purposes.

Ubiquitous technologies and seamless progressions often seem to imply no barriers, obstacles or resistance to either mobility or engagement, but this apparent seamlessness may not be what is required for the most powerful kinds of learning. Illeris (2009) identifies four types of learning: cumulative (the addition of something entirely new), assimilative (the addition of new material to established schema), accommodative (changing established constructs to accommodate new material) and transformative (which involves not only changes in understanding of external material but, more profoundly, changes in perceptions of self). These four types of learning make clear that some types of learning have important divergent characteristics whereby learners may go beyond or disagree with material that they encounter as a result of resisting the easy addition of that material to what they already know, do or believe. They may also resist the way in which they are being asked to learn.

In discussing conditions for learning, Illeris (2009) argues for resistance as "a most important source of transcendent learning" and argues further that "it should be a central qualification of teachers to be able to cope with and even inspire mental resistance, as precisely such personal competencies, which are so much in demand – for example, independence, responsibility, flexibility and creativity, are likely to be developed in this way."

Understanding learning and its diverse purposes, particularly its transformative purposes, gives the notions of ubiquity and seamlessness specific characteristics. The mere presence of ubiquitous resources or the capacity to make seamless connections is not sufficient to guarantee (the most powerful kinds of) learning. Central to our argument will be a view of learning that involves two aspects. It involves sustained and technologically unproblematic interactions between learners (and others). But it also involves critical perspectives embedded in transformative purposes. Such a view requires ready access to information (including the experiences, views and representations of others) and the capacity to absorb, reflect on and reframe such information in collaboration with others, not necessarily for the purpose of accepting what is encountered or the way it is presented.

There are two reasons for this. First, learning often involves struggles to integrate new material. Second, an important aspect of these struggles to learn is often finding space to free oneself from dominant ways of thinking and associated forms of surveillance. Some of the very supports for access to material may also involve the removal of spaces in which to struggle with that material. As Leander et al. (2010) point out, "children's discretionary space has undergone an inversion in the past 40 years, from independent mobility in outside spaces to sequestered play inside homes or other adult-monitored spaces." A consequence of this is that young people seek to escape from monitored activities. Seeking control over their own spaces/connections and processes suggests that some of the reasons why children engage with ubiquitous technologies may be endeavours to transform their lives and to create some measure of personal control by seeking out spaces/connections away from adult-created ubiquitous oversight of their lives. It is in/through these spaces/connections that they can engage with non-convergent styles of learning or the learning of content that does not converge with adult expectations. Students engaging with ubiquitous technology involve taking advantage of ubiquity but at the same time endeavouring to disrupt some of the seamlessness of access for specific others in order to prevent others controlling the processes that they engage in. Alternatively, students may seek to create seamless access to experiences and content that was not "designed" for them. Clearly, these ideas are not unproblematic since they raise issues of who determines against what criteria and in what circumstances whether something is appropriate in content, relations and purpose for the uses of the technology. So ubiquity and seamlessness need to be viewed as problematic constructs for all those seeking to engage with them.

We will discuss ubiquity first because it is a prerequisite for seamlessness. Widespread (or pervasive, see Ark and Selker 1999) computing resources create the need for transitions and connections. We restrict the concept of ubiquity to resources and deliberately separate it from the issue of the purposes for which those resources are employed.

Ubiquitous Resources

The concept of "ubiquitous computing" was initially defined by Weiser and colleagues (Weiser 1991; Weiser and Brown 1996). This view of ubiquitous computing focuses on ways of using technology without conscious attention. Ubiquity emerges as the various devices weave themselves into the fabric of our everyday lives (Weiser 1991). Weiser and Brown (1996) described this sense of ubiquitous computing as "calm technology" while O'Malley and Fraser (2006) described it as technology that is so embedded in our lives that it recedes into the background. More recently the term has been used to include context-aware computing in which mobile devices can automatically connect with digital information sources and adapt to local circumstances without the user of the device having to deliberately control the actions (Moran and Dourish 2001). For these purposes, context has been defined by Dey et al. (2001) as:

> …any information that can be used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups, and computational and physical objects. (p. 106)

Notable in this definition is the inclusion of nondigital resources through reference to "any information … considered relevant". Since no human-based activities ever occur exclusively in a digital environment, a view of genuinely ubiquitous resources must incorporate both digital and nondigital resources. Understanding the role of digital resources as subordinate to human purposes – in particular in learning contexts – requires views of ubiquity that encompass supportive relationships between digital and nondigital resources (e.g. learning from physical conversations with people, information gathered from the museum or library books). Therefore, understanding what is done by learners in and between different contexts requires a more explicit framing of the purposes that learners have for learning and how they relate to the affordances of various technologies.

Technologies must meet specific requirements if they are to be considered compatible with ubiquitous learning. Based on the work of Chen et al. (2002) and Curtis et al. (2002), Ogata and Yano (2004) identified these requirements as (1) **permanency,** where learners never lose their work unless it is deleted on purpose; (2) **accessibility,** where learners are able to access their files, documents and data from anywhere; (3) **immediacy,** where learners are able to obtain information immediately; (4) **interactivity,** where learners are able to interact with teachers, peers or experts through synchronous or asynchronous communication, enabling knowledge development and transformation to occur more quickly and readily; (5) **situating of instructional activities,** such that learning is embedded in the learners' daily lives and across different contexts and (6) **adaptability,** where learners can get the right information at the right place in the right way. These characteristics are not unique to but are strongly enabled by the educational affordances that mobile devices such as smartphones and tablets can offer, as shown in Table 13.1.

Affordances that mobile technologies offer in enabling seamless learning have been discussed widely in the literature (e.g. Keogh 2011; Ng and Nicholas 2007;

Table 13.1 Requirements and examples of mobile-enabled resources for mobile seamless learning

Requirements *Based on* Ogata and Yano (2004)		Selected enabling tools
Adaptability: learners can get the right information at the right place in the right way	*Accessibility:* learners are able to access their files, documents and data from anywhere	Mobile devices: smartphone, tablet, laptop, netbook
		Apps: Dropbox; SkyDrive
	Immediacy: learners are able to obtain the right information immediately	Mobile devices: smartphone, tablet, laptop, netbook
		Apps: Web browser, subject-specific apps or learning objects, e.g. podcast or vodcast
Interactivity: learners are able to interact with teachers, peers or experts through synchronous or asynchronous communication, enabling knowledge development and transformation to occur more quickly and readily		Mobile devices: smartphone, tablet, laptop, netbook
		Communication apps: email, chat apps, text messaging, social network apps, learning management systems (e.g. Moodle, Edmodo), online specialised community forums
		Web 2.0 apps: Wikispaces for collaborative construction of educational artefact
Situating of instructional activities: learning is embedded in the learners' daily lives across different contexts		Mobile devices: smartphone, tablet, laptop, netbook
		Subject-specific applications:
		For science, data logging probes and software
		For history, visits to places such as museums to record interviews/ conversations, use of QR code reader for more information
		For math: spreadsheet input as data is collected, e.g. in statistical investigations of a social nature

Nicholas and Ng 2009; Shih et al. 2011). In this table, we have embedded *accessibility* and *immediacy* within *adaptability* because in order to adapt, the student will need to be able to access relevant information as soon as possible. The priority of each of these characteristics will, in turn, be influenced by the overall purpose of the activities that call on the resources.

Ubiquitous Learning

The concept of ubiquitous computing has led to the idea of "ubiquitous learning" and a plethora of papers relating to it in the last decade (e.g. Chen et al. 2008; Hwang et al. 2008; Jones and Jo 2004; Sakamura and Koshizuka 2005). One view of ubiquitous learning links mobile technologies to e-learning through ubiquitous access (e.g. Casey 2005). A limiting consequence of this perspective is that it presents ubiquitous learning as one form of e-learning linked with a particular kind of communication technology, mobile technologies. This view is too simple.

As defined (in approximately 2009) in the scope and concerns statement of *Ubiquitous Learning: An International Journal*,

> …ubiquitous learning is a new educational paradigm made possible in part by the affordances of digital media. The qualifications in this statement are crucial. 'Made possible' means that there is no directly deterministic relationship between technology and social change. Digital technologies arrive and almost immediately, old pedagogical practices of didactic teaching, content delivery for student ingestion and testing for the right answers are mapped onto them and called a 'learning management system'. Something changes when this happens, but disappointingly, it does not amount to much. (http://ubi-learn.com/our-focus/scope-concerns)

One of the interesting aspects of this characterisation is the uncertain meaning of ubiquitous learning. In the focus section of the same journal, it is described as something that "seeks to put the needs and dynamics of learning ahead of the technologies that may support learning" (http://ubi-learn.com/our-focus/). The ambiguities, tensions and qualifications within these statements are important because they highlight the need to define each term clearly in order to understand the assumptions behind and relationships between each of the terms. In particular, they highlight the need to clarify what we mean by learning and how this view of learning relates to the potential of ubiquitous resources.

In the same scope statement, Cope and Kalantzis (2009) are cited as offering seven moves associated with the broad direction of ubiquitous learning:

Move 1: To blur the traditional institutional, spatial and temporal boundaries of education.
Move 2: To shift the balance of agency.
Move 3: To recognise learner differences and use them as a productive resource.
Move 4: To broaden the range and mix of representational modes.
Move 5: To develop conceptualising capacities.
Move 6: To connect one's own thinking into the social mind of distributed cognition and collective intelligence.
Move 7: To build collaborative knowledge cultures.

Currently, views of ubiquitous learning acknowledge the pervasiveness of digital technologies but do not clearly attempt to formally integrate nondigital technologies even though they do not formally exclude them. For example, Cope and Kalantzis (2009) speak of broadening representational modes but do not define relationships between representational potential and purpose. Our construct of ubiquitous resources deliberately extends beyond ubiquitous computing to support desirable learning practices incorporating both digital and nondigital resources. Clearly, distinguishing resources from learning helps to reveal the need to be explicit about the relationship(s) that is/are envisaged between resources and purposes.

The resources are one part of the picture, but in situations of ubiquitous computing, use of those resources will require users to make connections between different resources and their uses. This is the issue of seamlessness.

Seamless Connections

Ishii et al. (1994) pointed out that seamless design in computer-mediated environments has two motivations: continuity and smooth transitions. Baker (1999) pointed out that:

> Metacomputing and seamless computing have the same basic goals[,] that of integrating distributed and heterogeneous systems into one integrated computing environment. (p. 885)

More recently, Fredriksson and Ghica (2012) produced a technical definition of seamlessness as follows:

> By 'seamless' we mean that the syntax and semantics of the distributed program remain the same as if it was executed on one node only, except for label annotations indicating on what node sub-terms of the program are to be executed.

Despite their different framing, what both definitions share is either the preservation and continuity in management of material when it moves from one environment to another or that diversity within environments is acknowledged but accommodated within a single frame.

These central, shared themes have been re-contextualised in notions of seamless learning, but the emphasis in seamless learning is on the connections and transitions between one environment and another associated with the purpose of developing knowledge, attitudes or behaviours. Different from most notions of ubiquity (but see Twidale (2009) for a perspective that explicitly engages with the diversity of resources within a ubiquitous computing perspective), seamlessness has had a central thread incorporating both digital and nondigital environments.

Seamless Learning

George Kuh's (1996) much cited specification of the *Guiding Principles for Creating Seamless Learning Environments for Undergraduates* originated in concerns that many tertiary students have two distinct experiences of college life: a formal academic learning experience and the less academic, out-of-classroom experiences such as social engagements as well as certain curricular and/or cocurricular activities. Kuh's advocacy of changing the relationship between these two experiences from being distinctive to being whole and continuous is his perspective on seamless learning. Studies by Kuh and other researchers indicate that the integration of out-of-classroom experiences impacts positively on students' learning and development in a variety of ways. Goodman (2007), citing studies by researchers such as Kuh (1993, 1995), Lambert et al. (2007), and Pascarella et al. (1994) indicated that out-of-classroom experiences impacted positively on students'

- Cognitive and knowledge development such that there were gains in critical thinking and problem-solving skills
- Development on a range of psychosocial characteristics such as attitudes, psychological well-being, the ability to work successfully in a group and career development skills

Kuh's (1996) formulation of seamless learning as bridging formal and informal learning and his guiding principles for creating seamless learning environments were prior to widespread recognition of the upsurge in mobile and pervasive information and communication technologies (ICT) and prior to the emergence of specific mobile technologies such as smartphones (but see Hills and Johnson 1996). The more recent elaboration and diversification of technological options means that seamless learning not only involves connections between in-class activities and activities elsewhere but also connections between different technologies both within and beyond the classroom – indeed, the expansion of the understanding of seamless learning has accompanied an evolving understanding of learning space that reflects a greater focus on connections within and between locations than on the locations themselves (see Leander et al. 2010).

These developments have accompanied computing devices becoming smaller, more affordable and mobile devices more functionally powerful as well as more accessible to the individual. Some connections and transitions involve the learner carrying a single device from one environment to another while at the same time intersecting with multiple other devices and applications in those environments. This extension was formulated as the concept of one-to-one person/device relationships where every individual student has access to his/her own personal, computing device (such as a tablet, laptop, handheld) with access to Internet information and resources. The concept was promoted by the G1:1 network that was conceived by Chan et al. (2006). The one-to-one concept advocated by the group argued for a specific view of seamlessness with implications for learning. That view of seamlessness was that:

> By enabling learners to learn whenever they are curious and seamlessly switch between different contexts (such as between formal and informal contexts and between individual and social learning) and by extending the social spaces in which learners interact with each other, these developments, supported by theories of social learning and knowledge-building, will influence the nature, the process and the outcomes of learning. (pp. 25–26)

Echoing Ishii et al.'s (1994) thinking, the switching between different environments involved in seamless learning is referred to as the "continuity of learning" by Sharples et al. (2012). This continuity experienced by a person transcends particular combinations of locations, times, technologies or social settings. Sharples et al. further stated that there is an emerging switch in the focus on seamless learning from earlier perspectives. The previous focus was on software design for mobile devices to enable learners to switch quickly from one learning activity to another to continue with their learning. The more recent focus is on how access to multiple devices can enable the flow of learning across boundaries between formal/informal spaces and the transitions between school/university/work/home settings to support personal learning journeys. Reflecting on this less managed view of learning, they identify two further significant characteristics: personal inquiry learning ("active exploration of an open question") (p. 5) and rhizomatic learning ("boundless exploration across many fronts from different starting points') (p. 5). This focus on smooth flows reflects a requirement of seamless access to resources but may not be the best means of promoting powerful learning since it may prioritise Illeris' (2009) cumulative or assimilative learning over accommodative or more particularly transformative learning.

A detailed conceptualising of seamless learning by Wong and Looi (2011) and Wong (2012) teased out 10 characteristics delineating seamless learning that consider the affordances of technology in extending the spaces and contexts for seamless learning. These characteristics of seamless learning, assisted by mobile technology (hence labelled mobile-assisted seamless learning), are that learning traverses across (1) time and (2) location; seamless learning encompasses (3) formal/informal learning, (4) personal/social learning and (5) physical/virtual worlds; (6) there is access to ubiquitous knowledge; (7) learning combines the use of multiple devices; (8) seamless learning entails the ability to switch seamlessly between multiple learning tasks; (9) there is knowledge synthesis and (10) instructions encompass multiple pedagogical models. The framework's purpose was to bring together technological resources and pedagogical means to support learner's meaning making and foster habits of mind for lifelong learning. In this view, seamless learning exploits the affordances of ubiquitous computing and engages with ubiquity in ways that are experienced by the learner as continuous and without disruption. However, only in their ninth principle do they begin to engage with what might be a view of purpose. The very sense of seamlessness may indeed background the struggle and resistance that is likely to be an essential ingredient of transformative learning. From this perspective, it is vital to distinguish seamlessness in technological connectivity from the purposes and processes that may enable truly powerful learning to occur across contexts and relationships.

The lack of attention to purposes of learning means that the shared focus on affordances and contexts results in many similarities between Wong and Looi's (2011) seamless learning and Ogata and Yano's (2004) ubiquitous learning. For example, as we show in Table 13.2, all of Wong and Looi's (2011) seamless learning characteristics could be mapped onto the conditions of Ogata and Yano's (2004) ubiquitous learning framework. While nearly all of the overlaps are explicit, one at least needs more interpretation. The characteristic of permanency in the ubiquitous learning framework is implied in the seamless learning framework since only a deliberate action of removing a file would result in loss of an individual's work while learning seamlessly. Permanency is implied since seamlessness cannot exist unless the same material is accessible in multiple contexts (see Baker 1999; Fredriksson and Ghica 2012).

Table 13.2 Mapping of seamless learning characteristics (Wong and Looi 2011) onto ubiquitous learning characteristics (Ogata and Yano 2004)

Ubiquitous learning	Seamless learning
Permanency: learners never lose their work unless it is deleted on purpose	Implicit
Accessibility: learners are able to access their files, documents and data from anywhere	Encompassing formal and informal learning
	Encompassing physical and digital worlds
	Across time
	Across locations
	Ubiquitous knowledge access
	Seamless switching between multiple learning tasks
	Combined use of multiple device types
Immediacy: learners are able to obtain information immediately	Ubiquitous knowledge access
	Combined uses of multiple devices
Interactivity: learners are able to interact with teachers, peers or experts through synchronous or asynchronous communication, enabling knowledge development and transformation to occur more quickly and readily	Encompassing personalised and social learning
	Encompassing formal and informal learning
	Encompassing physical and digital worlds
	Across time
	Across locations
	Knowledge synthesis
Situating of instructional activities: learning is embedded in the learners' daily lives across different contexts	Encompassing formal and informal learning
	Encompassing personalised and social learning
	Encompassing physical and digital worlds
	Across time
	Across locations
	Knowledge synthesis
	Encompassing multiple pedagogical or learning activity models
Adaptability: learners can get the right information at the right place in the right way	Encompassing formal and informal learning
	Encompassing physical and digital worlds
	Across time
	Across locations
	Ubiquitous knowledge access
	Combined uses of multiple devices
	Seamless switching between multiple learning tasks

However, there are also differences. While both ubiquitous learning and seamless learning are promoted as ways of engaging with pervasive digital technologies, a distinguishing feature of seamless learning is the awareness of the transitions within/between digital technologies and nondigital resources. We have pointed to the differences between ubiquitous learning and seamless learning above, but nevertheless one of the significant issues is the overlap between the two constructs. For example, the six requirements for ubiquitous learning are necessary for seamless learning to occur. For this chapter, we merge the requirements for ubiquitous learning into our pedagogical framing of mobile seamless learning.

Towards a Pedagogical Framing of Seamless Learning

In framing a pedagogical model for seamless learning, educators have a key role to play in assisting students to learn between borders or seams of learning spaces (e.g. physical/virtual seam). It is here that the transformative purposes of learning need to exploit but also be differentiated from the seamlessness of the connections between technologies. In line with the views of Schenker et al. (2007), we understand learning as “the processing of encountered information that leads to changes in knowledge, skills, beliefs, abilities, and behaviours” (p. 172). We extend “information” to include experiences, values and representations. The notion of seamless learning emphasises how this processing can occur through a variety of modes and modalities unconstrained by time, location or the switching from one environment to another to learn about a certain topic or concept or to solve a problem through investigation. The switching between the contexts that are created could be deliberate (conscious and planned) or instinctive (unconscious and instantaneous). For example, a deliberate action of seamless learning for a student learning English as a foreign language is to join in a conversation online (such as reacting to a blog about a topic of interest or making comments on an online newspaper article) and mobile when the individual is able to check on the progress of and contribute to the conversation using his/her smartphone while sitting in a train on the way home. A less planned action of seamless learning would be the sighting of unfamiliar graffiti painted on the backyard wall facing the train line and activating the smartphone’s dictionary app to find the meaning of the graffiti or the use of the device’s image recognition capacity to seek information about the graffiti. This is the kind of *adaptability* that is one of the requirements of seamless learning. From a pedagogical perspective, teachers would provide the guidelines for learning processes and relationships that would transcend formal and informal contexts for planned seamless learning where a task needs to be completed, for example, the process of gathering data for the creation of an artefact or the solving of a problem across multiple contexts. For less planned seamless learning, teachers would have already worked on strategies for dictionary use but would also be required to encourage students as much as possible to bring into the classroom things that they have encountered outside the classroom. In the case of language learning, a relevant question would be “what new and interesting words or images did you see outside class this week?" Transformative purposes would be encouraged by asking students to reflect on what frustrates them and alternatives that they can imagine or locate to overcome those frustrations.

For teachers considering seamless learning, Sharples et al. (2012) argued that the approach to structuring students' "seamless learning" should not be too heavy-handed as a heavy-handed approach would almost certainly be counterproductive. However, it is appropriate to assist students in developing their personal learning across multiple environments and to develop the desire to find out about things that are unfamiliar so that they are informed citizens when participating in school-based projects or interacting with the wider community. Hence, within the teacher's design of seamless learning, there should be freedom for the students to select the type of learning space and/or learning resources that they feel most comfortable with in completing tasks across multiple contexts.

In elaborating the principles of seamless learning, we need to analyse seamless learning from three perspectives: context, nature of learning and technological constellation.

Context

Contexts for learning can be established in many different ways (Westera 2011). While many views of context see it as something coming "from the outside" in which actions and interactions are embedded. Westera (2011) illustrates how the meditational potential of virtual technologies itself shapes context. He points out (p. 203) that the virtual world can create its own "reality/context". "…what counts is not realism or authenticity but credibility. Even fictitious, non-existing, non-authentic realities may provide valuable learning experiences…." We see this as an alignment between learner purposes and learning activities. We see attention to learner voice or control translated through the teacher's view of critical challenge as a key aspect of the creation of credibility. Westera (2011) goes on to point out that

> Whereas the creation of an appropriate learning context for learners used to be one of the main challenges of teachers and education designers, learning context tends to include more and more emergent components that are induced by the learners themselves, dependent on the media they use and the conditions for learning they create themselves. (p. 203)

This way of thinking shows how the involvement of digital technologies changes the perspective on the learning space. It is no longer (only) a classroom to which other things are brought but rather a context in which multiply located "credibilities" are simultaneously engaged with. The roles of both teachers and learners in creating context are reinforced rather than viewing technologies as things that "bring" context to the learning space. Leander et al. (2010: 362) refer to "learning reciprocity".

While referring to computer games Westera et al. (2008) explain that the required authenticity of the environment is not necessarily related to the ways authenticity is presented. Outstanding graphic landscapes, character animations and sound in games may certainly contribute to enhance authentic experiences, but various studies (Reeves and Nass 1996) indicate that only very little representational or technological effort is necessary to provoke true interpersonal responses. What counts is not realism or authenticity, but credibility. Even fictitious, nonexisting, non-authentic realities may provide valuable learning experiences (Westera 2011: 203).

The Nature of Learning

Seeing context as emergent rather than as established and brought in "from the outside" underlines the empowered and empowering roles of the participants since it acknowledges the roles that the participants play in making the interaction credible in their own eyes and in the eyes of those they are interacting with. A corollary of this view is that learning, both in general and specifically in learning with mobile devices, must also be an empowered and empowering process.

One of the dilemmas in this claim is that learning necessarily involves a conflicted perspective – if there is something to learn then the learner is necessarily less empowered in relation to the thing to be learned than someone who already controls more aspects of that knowledge or behaviour. On the other hand, learning occurs most powerfully when the learners' existing experiences and identities are acknowledged and incorporated as both valid and useful elements of the learning process. Learners do not know "nothing" they know about specific things that differ from what confronts them in a learning task. Sometimes the difference is so substantial that what is learned turns what was previously known on their head.

To empower the learner the organisation of learning must structure a relationship between what learners already know and what they are attempting to gain control of. Perceiving and experiencing this as a purposeful relationship is part of what gives the process the necessary credibility to motivate the learners' sustained engagement. This credible relationship is part of the empowerment of the learner since it gives the learner a basis for reflecting on (rather than just absorbing) what the learning task offers (see Illeris 2009 on the power of resistance as a reason why cumulative approaches may not be the most credible). If something to be learned is seen as so distant from what is already known that no credible pathway to the new can be imagined, no context for learning has been established.

In learning with mobile devices, the specific challenge is for the technologies to support the establishment of credible relationships with other learners and with the learning object. As the comments above imply, credible relationships involve mutuality – learners must be able to both reflect with each other on what they already know and on the task that confronts them. They must also be able to analyse (in potentially quite different ways) what the task is and how to go about it, including what aspects of the task create resistance of various kinds. So the nature of such learning is group-based (i.e. collaborative), tentative, critical and reflective; engages with both knowledge/understandings/representations and emotions; is incremental where multiple representations will compete for credibility/verification through the alternative understandings/perspectives that they offer and it is, therefore, recursive. It accommodates all four of Illeris' (2009) types of learning. Learning therefore both builds on and transforms knowledge, relationships, beliefs and ways of acting but in a collaborative manner. It is this purpose that must be served by the technologies and this purpose in turn helps to define what seamless learning has to embrace (see also Cope and Kalantzis 2009).

Technological Constellation and Non-technological Resources

As indicated above, a technological constellation that will support seamless learning must embrace both digital and nondigital technologies and resources. This can be achieved via either single or multiple devices; though in practice, a single device that is small enough to be mobile is unlikely to have all of the affordances that are needed for the full range of purposes entailed by learning, and a device that is large enough to accommodate all the affordances is less likely to be fully mobile. Therefore in practice, the technological constellation will most frequently consist of multiple devices. Some of these relationships are depicted in the three-dimensional pedagogical model for mobile seamless learning in Fig. 13.2 below. Pedagogy in the figure mediates the constructs of "context" and "content" to bring about seamless

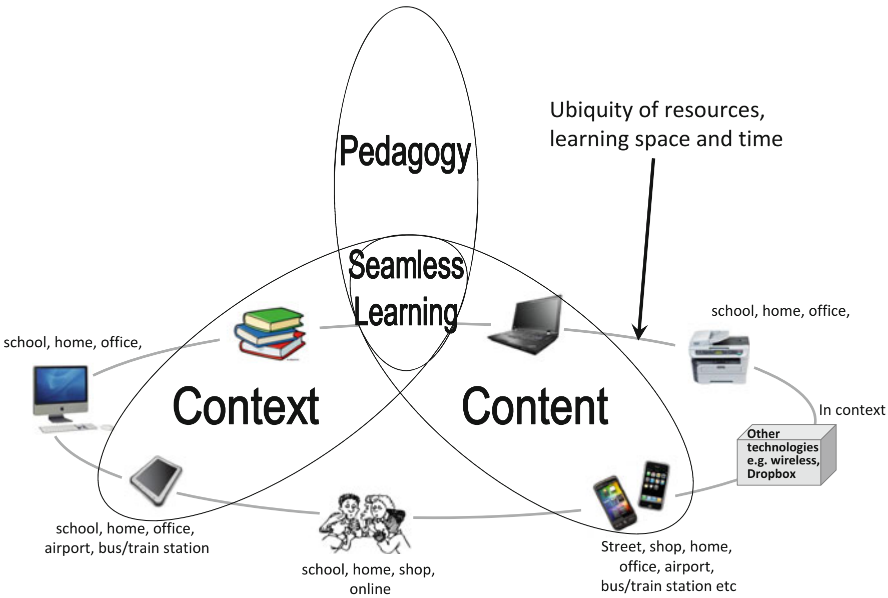


Fig. 13.2 Model of the pedagogical considerations of seamless learning: context, content and ubiquity of resources, learning spaces and time

learning for the students. The ubiquity of computing and other resources that includes humans and other physical resources encompasses "context" and "content" to bring about continuity in learning that is facilitated by the pedagogy designed by the teacher. In this view, learning is not bound by time, and the learning spaces change to adapt to the created context of learning in the model. The distributed nature of the access to a variety of sources of information or means of reflecting on experiences in interaction with others calls for interpretations of learning that are characterised by the transformation of understanding and the ability to question experiences and information through multiple contexts and in multiple environments (see also Ng et al. 2010). The key features of seamlessness that are required for such learning are that (1) material should be preserved across devices and contexts, (2) its format should be appropriate to the device/context in which it is accessed and (3) it should be appropriately manipulable in whatever context it is accessed.

An Example of Seamless Learning

As an example to demonstrate the pedagogy of mobile seamless learning according to our model in Fig. 13.2, we have made use of the study of the topic of the circulatory system by year 9 students. The topic has credibility for a number of reasons. First, the issue is one that is directly experienced by the students in their engagement (or lack thereof) with physical activity. Second, it is reinforced in general media attention to issues such as obesity campaigns and heart attack prevention measures (though students may resist such public service announcements as "boring"). Third, experiences with human organs and anatomy have sufficient of a ghoul factor to be "cool" because they can be an occasion for relating experiences of fear. Virtual engagement with heart dissections is sufficiently removed from the direct experience to remove some of the threat and very profound personal resistance. The opportunities for open-ended activities in pairs or groups create ways in which learning reciprocity can be engendered, including where discoveries can be related to both peers and teachers. Using Illeris' (2009) framing, there is opportunity for cumulation, assimilation, accommodation and transformation to varying degrees according to the backgrounds, experiences and beliefs of the various students.

As illustrated in Table 13.3 below, the pedagogy involved the "normal" teacher-directed learning of the content of the circulatory system – parts of the heart, types of blood vessels, types of blood, how the heart works, etc. This aspect of teaching transcends formal and informal environments (e.g. homework and revisions at home), and learning is scaffolded through a variety of class-based activities, including group work such as discussions and undertaking science experiments. As all year 9 students in Australia have laptops, the learning is encapsulated in these laptops and hence portable between school and home. In the formal classroom context, the students interact with a variety of learning resources – wall charts of the heart and blood vessels, discussion with teachers/peers, use Web-based resources (e.g. content and simulations) and communicate with productivity tools in the laptop

Table 13.3 An example of mobile-enabled seamless learning of the circulatory system for year 9 students

Pedagogy				Learning space				Individual or collaborative	
Content and strategies		Context	Learning resources and uses	Formal	Informal	Physical	Virtual	Indv	Collab
Learn content about heart, blood, vessels		Classroom and home	Teacher's explanation, various resources, e.g. book, charts, IWB, mobile viewing of animations, YouTube videos, mobile-based research	✓	✓	✓	✓	✓	✓
Investigate and report on the heart rates of	Individual and class members	Classroom	Timer (watch or mobile phone), spreadsheet for recording and charting self and peers and family's pulse rates	✓		✓		✓	✓
	Family members	Home			✓	✓		✓	
	Animals, e.g. rat, elephant, dog, etc.	Classroom and home (Internet search)	Mobile-based research and spreadsheet entry (laptop, tablet, smartphone)	✓	✓		✓	✓	
Group work: create a multimedia online poster of a heart or blood disease/disorder		Anywhere access to online app: Glogster.com	Laptop, tablet, smartphone to research Internet for information and for communication with peers, e.g. exchange of topic-specific images, ebooks and videos		✓		✓	✓	✓
Group work: make model of a heart with major blood vessels		Homework	Access online materials via mobile devices for images and help to construct a model, e.g. at http://www.ehow.com/how_5556658_build-heart-science-project.html		✓	✓	✓	✓	✓
Virtual dissection of the heart		Classroom Anywhere	Online simulation, teacher's explanation, review on train or at home on mobile, answer and submit questions online	✓	✓	✓	✓	✓	
View the human anatomy exhibition		Exhibition venue	Mobile-captured images of preserved exhibits, QR-coded information and virtual tours of various aspects of the circulatory system. Send images to team		✓	✓	✓	✓	
Listen to an expert talk about drug effect on the heart and the circulatory system		Classroom Anywhere	Invited practitioner; video conferencing technology, e.g. Skype; review recorded talk anytime, anywhere on mobile and incorporate into online poster	✓	✓	✓	✓	✓	
Staged online quizzes		Anywhere	Mobile access to online quizzes and check for instant feedback; discuss uncertainty with friends via chat apps		✓		✓	✓	✓

(e.g. report writing using a word processor or chart graphs in a spreadsheet). These seamless movements between contexts (e.g. from Internet search to conducting a science experiment) and between resources in the classroom require a level of technology use where it recedes into the background and (Weiser 1991; Weiser and Brown 1996) comes to be used unconsciously when there is a need to fulfil.

For seamless learning to continue beyond the classroom, the teacher needs to design into the pedagogy explicit opportunities for the students to continue with the learning of the topic. The strategies shown in Table 13.3 above provide ample opportunities for the students to switch between contexts and tasks and to learn wherever and whenever they have time. Students could also extend their interest in the learning, for example, in undertaking an "investigate and report on the heart rates of animals" task. In this task they could extend their investigation to research what the hearts of different types of animals look like and how they function. They could compare the structure and function of different animals with that of humans and extend that learning to as many types of animals as their curiosity includes. With an appropriate pedagogy that would extend the credible contexts created so that the students' individual learning journeys meet again in the classroom, students can learn whenever their interest is stimulated without boundaries of time or place but with a responsibility to share their learning with others. Hence an effective pedagogical design of mobile seamless learning would be the design of learning that on the one hand stimulates the desire to learn and provides the students with opportunities to be immersed in a variety of contexts that will occupy the mind on a continual basis and on the other hand creates credible contexts for the sharing with others of what they have learned.

Conclusion

In this chapter, we have argued that seamless learning is a term with a history of intimate but under-specified connections with both ubiquity and seamlessness. We have shown how all three terms, ubiquity, seamlessness and learning, need to be defined carefully in order to understand how they relate to each other. We have offered a way of specifying the nature of learning in "seamless learning". By specifying how "learning" should be understood, we have sought to identify the crucial aspects of both ubiquity and seamlessness that need to be invoked for seamless learning to become an empowering practice.

Carefully designed mobile seamless learning could provide meaningful learning for students as it breaks down the barrier of the perceived didactic education that takes place in classrooms and offers more control of the learning to the students but in ways that also involve responsibility to other learners. Learning is also more credible as the students are encouraged to learn by means that they select (e.g. search the internet or ask an informed person, physically or virtually, or join an online forum) including expanding the options for when and where they want to learn.

(continued)

There are implications for teachers designing seamless learning facilitated by mobile devices. An implication for teachers designing mobile seamless learning pedagogy is that they need to be aware of the types of learning that will occur and the types of learning spaces that students could immerse themselves in during the learning. Credible contexts mean that students will be required to make judgements about which kinds of experiences will be worthwhile and how they can make such decisions. Another implication is that the teacher needs to be aware of the safety issues of learning spaces and, for equity purposes, ensures the availability of required tools to all students. A third implication is that the teacher will need to know about available mobile apps for learning, understand the functionalities of different mobile devices and ensure that the learning materials, e.g. videos, animations, simulations, podcasts, vodcasts and communication apps are downloadable to mobile devices the students possess so that the students can learn on the move. The teacher would also need to teach the students explicitly about the tools used and the technological constellation. For example, Ng and Nicholas (2009) found that students do not necessarily know how to transfer skills from desktop tools (e.g. Excel) to the more constrained versions in mobile devices.

Hence, clearly addressing not only the contexts or affordances of seamless learning but crucially the varied learning purposes that need to be invoked creates ways in which the learning experience can be perceived as credible and can address some of the rapidly shifting spaces in which students both locate themselves and seek to gain some control over their lives (Leander et al. 2010). Addressing the purposes of learning and particularly the capacity for learning to be transformative presents a challenge to flat perspectives on seamlessness that see learning as a bland and relatively uncontested process that occurs without interruption across contexts, spaces and technologies. We see learning as both more interesting and diverse and more creative than that view.

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Chapter 14
Language as a Bridge Connecting Formal and Informal Language Learning Through Mobile Devices

Agnes Kukulska-Hulme

Abstract Informal learning plays an important role in language learning and mobile device ownership fuels its growth, thanks to the availability of educational apps, massive scale services delivered by network operators and emerging designs for situated learning in authentic communication contexts beyond the traditional classroom. This chapter shows how connections between formal and informal language learning may be made through the use of mobile technologies and explores the mutual influence of these spheres, with particular reference to the role of language. Language is the focus of learning but also the means by which learning happens, which gives it a unique mediating and facilitative role. The potential for conversational language to act as a new bridge between formal and informal settings is explored. Motivations for language learning are changing and they will have an influence over what types of learning appeal to new generations of language learners of all ages. Faced with an abundance of resources on the Internet and on their mobile phones, learners will often look for more structured environments and some degree of guidance. The opportunity is there to create learning environments and designs that incorporate the effective use of mobile technologies but that also consider how new social contexts influence the language that is being used and learnt. An example of this is described with reference to the MASELTOV project which is creating innovative context-aware smartphone services for migrants and provides a fertile ground for imagining the future of language learning.

Introduction

Language learning is one of the key disciplines to have benefitted from mobile learning to date. Reasons for this include the nature of language learning content which largely lends itself to being divided up into portions that are suitable for access on mobile devices, the relative ease with which audio-visual media may be

A. Kukulska-Hulme (✉)
Learning Technology and Communication, Institute of Educational Technology,
The Open University, Milton Keynes, BUX MK7 6AA, UK
e-mail: agnes.kukulska-hulme@open.ac.uk

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utilized to create a portable, flexible learning experience, and the fact that ‘non-formal and informal education plays a key role for language learning’ (European Commission 2012, p. 16). On a global scale, the enormous demand for learning English is increasingly being satisfied by a massive provision of subscription-based mobile learning content and services, sold directly to consumers by telecom network operators, device makers and content suppliers (Adkins 2012). For educators and researchers, interest in mobile language learning stems from the challenge of assisting learners as they apply and extend their language skills in authentic communication contexts beyond the classroom or other environments in which learning takes place. Kenning (2007) highlighted the opportunity for mobile technologies to support situated language learning ‘anchored in a real-world setting’ (p. 192), and this has subsequently become an expanding area of research and practice.

The unique benefits of mobile learning include the ability to bridge formal and informal learning (UNESCO 2013), which for language learners may be realized through supplementary out-of-classroom practice, translation support when communicating with target language speakers and the capture of difficulties and discoveries which can be instantly shared as well as being brought back into the classroom (*ibid*, p. 21). Mobile learning can deliver, supplement and extend formal language learning; or it can be the primary way for learners to explore a target language informally and direct their own development through immediacy of encounter and challenge within a social setting. What is missing is sufficient explicit connection and interchange between these two modes of learning, one of which is mainly formal and the other informal. Consequently, there are missed opportunities in terms of mutual benefit: formal education remains somewhat detached from rapid socio-technological change, and informal learning is frequently sidelined or ignored when it could be used as a resource and a way to discover more about evolving personal and social motivations for learning.

The aim of this chapter is to show how connections between formal and informal language learning may be made through the use of mobile technologies and to highlight the mutual influence of these spheres, with particular reference to the role of language in this process. Motivations for language learning are changing, which means we need to re-examine how learning should be designed for the next generation including those returning to language study. Future educational scenarios could well involve cycles that interleave or combine formal and informal learning. As lifelong learners increasingly switch careers and move between countries and continents to develop their language competences for different purposes and settings, their learning requirements will not stay constant. They will continue to need some guidance and structure, participation in a learning community and support from others, a sense of progression and achievement and at times formal recognition or credit; however, they will also welcome the chance to use their personal portable technologies in whatever ways can help solve immediate problems and enhance their learning. The classic distinction between formal and informal learning is breaking down, for example, through initiatives to promote the formal recognition of informal prior learning (Smith and Clayton 2009) and as a corollary of mobile device ownership (Cook et al. 2008). This is paralleled by profound changes in language usage under the influence of the Internet and the mobile phone (Crystal 2001, 2008). In this chapter, the potential for conversational language to act as a new bridge between formal and informal settings is explored. This leads to consideration of new opportunities for developing language skills and cultural awareness together with transferable life and employment skills, as well as the best means of delivering these opportunities to prospective learners.

Purposes of Language Learning

Foreign language pedagogy has long been bound up with available audio-visual media and shifting opinions as to the purposes of language learning, which have defined teaching approaches and methods. Macaro (1997) describes how during the 1970s, 1980s and 1990s an emerging emphasis on communicative competence gave rise to Communicative Language Teaching (CLT) which was adopted internationally yet was characterized by 'an enormous eclecticism' (p. 42). In recent times we are witnessing a convergence of views around the importance of communication across cultural boundaries rather than focussing specifically on language learning and acquisition, especially where the language teaching policy is concerned. The American Council on the Teaching of Foreign Languages has declared that the most important goal is 'the acquisition of the ability to communicate in meaningful and appropriate ways with users of other languages' (ACTFL 2006, p. 3), which will also enable participation in multilingual communities in a variety of contexts and in culturally appropriate ways. This is echoed by Duff (2008) in relation to economic imperatives in the Asia-Pacific region, where what matters is the 'ability to communicate effectively with people across languages, cultures, communities, and new digital media' (p. 1). Responding recently to concerns about the foreign language skills deficit in the United Kingdom and its economic implications, a report commissioned by the British Academy (Tinsley 2013) stresses the need to further diversify existing language provision and provide more applied and inclusive language courses at all levels. Employers declare that they value both language skills and the international and cultural awareness that comes from speaking a foreign language.

Several decades ago, when substantial work on motivation in second language acquisition identified integrative and instrumental motives (Gardner and Lambert 1972; Gardner 1985), instrumentally oriented learning meant attending classes with a determination to gain academic credit or improve one's prospects for employment or promotion. Research has shown that alongside foreign language skills, employers value certain transferable skills in university graduates and that these include self-management and the ability to use their own initiative (Lowden et al. 2011). This is of interest as there is emerging evidence of a good alignment between the deeply personal character of mobile devices and the exercise of learner autonomy, specifically in relation to language learning (Díaz-Vera 2012). The concept of self-access language learning emerged in the early 1980s (Gardner and Miller 1994) and is strongly associated with the development of learner autonomy. Autonomy engages both the metacognitive and the affective domain, and for language learners this has special significance since acquiring a second or foreign language ultimately changes the learner's identity (Fortunati 2002; Elliott 2010). This is where integrative motivation comes into the picture: the desire to gain access to another culture and the people who are already part of it. Identity change should begin with recognition on the part of educators that the learning is personal: language learners bring to the classroom 'a personal history and personal needs that may have little in common with the assumed background and implied needs on which the curriculum is based' (Little 2004: 70). This then suggests that a language learning programme or curriculum should be adaptable, with the possibility of allowing learners to determine at least some of the content and activity types themselves, but the means to achieve it have remained under-explored. One way forward is through CLIL (Content and Language Integrated Learning) which combines subject and language learning. For example, Smith et al. (2013) refer to the work of Banegas who reported an initiative where lessons and materials were negotiated between teachers and secondary school students; the students voted for topics and suggested sources. In this instance, set course books were valuable for grammar learning but skills development was negotiable.

Taking the learner-centric approach a step further, we must also consider why particular groups of learners have a need for certain aspects of foreign language learning and rehearsal, notably listening and speaking. They include:

- Migrants. These learners frequently have to practise listening and speaking skills in order to seek work or improve their social integration in another country. Palalas's (2012) research focused on the use of mobile technology to expand learning beyond the classroom and proposed some guidelines for a mobile system to support the development of listening skills in those who are learning English in relation to specific jobs, enabling them to practise at any time of the day or night.
- Students spending time abroad. In addition to improving their language competency, these learners may be collecting information that they can use to further their studies. For this group, Shao et al. (2007) designed an informal mobile group blog, enabling the students to share observations about local language and customs and thus get more personal value out of their study abroad experience.
- Professionals in global companies and organisations who may be required not only to communicate in a foreign language but also to participate in multilingual meetings (Mondada 2012).
- Heritage language learners. *Foghlaim Ón Nuatheicneolaíocht* (learning through new technology) was a mobile learning intervention aimed at enhancing the teaching and assessment of spoken Irish language in secondary schools throughout Ireland (Arrigo et al. 2010).
- Distance learners who want to build their confidence. This was the case with the distance education students participating in a study conducted by Demouy and Kukulska-Hulme (2010), for whom a specially designed mobile phone facility was a welcome additional opportunity to practise aural and oral skills, often at home.

- Learners with specific learning challenges that require a more personalized approach and targeted speaking or listening practice. It has been recognized for some time now that a foreign language course can trigger learning difficulties that students thought were behind them, or it can reveal previously undiagnosed learning problems (Schwarz 1997). Mobile learning research currently addresses how learners with disabilities or special needs can be assisted through the use of appropriate software on a mobile device (e.g. Fernández-López et al. 2013) although this is not yet specific to language learning.

Common requirements for these groups include personalized use of technology and being able to integrate life and work experiences with learning. This can be achieved through informal learning, although taking part in some formal classes is usually still essential. The next section considers the role of language and its evolution in connecting these spheres.

Language as a Bridge

The idea of bridging formal and informal learning evokes a metaphor that suggests two entities remaining separate, but with an easy means of crossing over from one to the other. This metaphor is subsumed within the concept of learner-centric seamless learning (Wong 2012) and connects with other aspects of seamlessness including the ability to move easily from a personal to a social space and being free from constraints of location and time. At times formal learning takes place in informal settings, and informal learning in formal settings (Wong and Looi 2011); therefore, the setting itself does not completely determine the level of formality. This can also be said of language use: the setting is a strong determinant, but formal language is at times used in informal settings and informal language in formal ones.

In parallel with considering how mobile technologies may act as a bridge between formal and informal language learning, it is necessary to reflect on how language itself acts as a tool and is implicated in the externalization and representation of formality. The process of education with its norms and conventions is one way in which language use in society is established and perpetuated, but it is also the ground on which issues of language use are questioned and examined, including the functions of language in society and in education (e.g. Wells 1999). Mobile learning is not only a means of learning a language; it is also a lens with which to view language usage and an instrument that can change its use.

The traditional approach to overcoming linguistic and cultural distance is by means of translation. As a highly skilled activity, translation requires human expertise which is being partly replaced by automation. Ambiguity, non-equivalence and cultural references continue to pose a challenge to automation, while Internet and mobile device users' creative and informal use of language is a new development that once again puts high-quality fully automatic translation out of reach, just as it was becoming feasible. Nonetheless, translation tools are now widely available and mobile apps that translate words and phrases can be used in the midst of conversation as a means of support (where this is deemed socially acceptable). When the translation is ‘spoken’ by the mobile device, the requirement for the interlocutor to be literate is removed, although the voice which is generated is not matched to that of the human speaker and it has a rather formal tone. Thus speech production on a mobile device gives a rather formal flavour to what might otherwise be an informal exchange. If informality is to be conveyed at the same time, this must be done through other means such as gesture and facial expression. Interpreting skills, which are used in oral communication and are very different from the skills of written translation, include advocacy, cultural brokerage and provision of emotional support (Butow et al. 2012).

The traditional distinction between written (mainly formal) and spoken (mainly informal) language gives rise to ‘conversation’ as an informal speech genre with certain distinguishing norms and features (based on Crystal 1987; Zhang 2012):

- Everyday conversations generally do not have careful thematic planning.
- The language is characterized by a degree of non-fluency, rapidity and loosely connected constructions, with some elements being implicit (since context helps to clarify meaning).
- Vocabulary is limited, and there is use of non-standard and deviant forms, as well as placeholder words standing in for words that cannot be retrieved quickly from memory.
- Conversational turn-taking affects the manner and pace of delivery, e.g. speeding up at the end of a sentence.

Although such characteristics are challenging for language learners, at the same time the interpersonal malleability of conversation – its inherent flexibility, its tolerance of ambiguity and error and the opportunity to use voice modulation and gesture and to negotiate meaning – could be more conducive to foreign language production than the stricter requirements surrounding formal and written discourse. In practice however, conversational language is often taught as a series of exemplar dialogues with set phrases and predictable outcomes: informal discourse is thus presented in a formalized or even a formulaic way. The potential to engage in authentic reciprocity or to develop the capacity to respond to an unexpected situation is necessarily underutilized in traditional language classes which must cater to the needs of whole groups or cohorts – and the requirements of examinations and tests – rather than individuals’ needs or desires in terms of communication and self-expression. Limited linguistic input from a single teacher further constrains what can be achieved in such classes. External resources, including the Internet, expand the repertoire but not necessarily the ability to adapt content and interaction to an individual learner or situation. Mobile technologies do not imply or guarantee individualization; however, there is scope to implement this in various ways (see, e.g. Petersen et al. 2009). Petersen et al. (2012) suggest that through the use of an appropriately designed mobile app that combines ideas from crowdsourcing and social networks, learners can create language learning content that can be shared by others in their group and that this can enable them to use language more creatively in their conversations. It remains to be seen whether there will be strong evidence that such creativity will indeed be more likely when using this app, but the possibility is intriguing.

Digital and mobile media are changing language use at the same time as they are a means to extend the use and learning reach for any given language. Ever since the advent of electronic communication, expectations and practices that once made clear distinctions between spoken and written language are no longer the same (Crystal 2001). Practices have continued to evolve with the recent explosion of instant communications, social media and increasingly common use of visuals not only as illustrations but as substitutes for words. Furthermore, a strongly interconnected, social, user-centred web makes it more common to encounter foreign languages than was the case with the previous generation. For example, there is more opportunity to become curious about the meanings of foreign words and sentences encountered casually in environments such as globally accessible microblog posts, discussion groups and forums. This may help break down language barriers over time; however, such a suggestion is not unproblematic because encountered usage may be non-standard. Kenning (2007) describes the Internet as a 'prime site of struggle between conformity and unconventionality' (p. 67) when it comes to language evolution and points out that exposure to many language variants can be unsettling and confusing for language learners. We can hypothesize that mobile Internet access might even add to the difficulty, since mobile devices are not designed for simultaneous access to multiple resources such as definitions, examples, comparisons and translations, as well as to people who can help. Nevertheless, the question arises as to whether such unplanned foreign language encounters can constitute a novel type of motivation for learning diverse languages, for exploring variety within languages or even for a re-conceptualization of how language learning should take place. Exposure to informal and conversational foreign language usage (which can be observed and studied at leisure) may yet become a new bridge to language learning, but perhaps not without conscious consideration of how this could happen.

Emergent Forms of Language Learning

It seems reasonable to suggest that all new opportunities, models and tools for developing language skills and cultural awareness should be considered for the modern world, with additional evaluation of how they support transferable life and employment skills such as teamwork and collaboration, learner self-management and autonomy. Mobile learning is certainly a strong contender. McFarlane, Roche and Triggs (2007) identified three pedagogical models for mobile learning, from fully teacher-directed to fully autonomous learning, with 'teacher-set' activity in between, and an analogous set of models was proposed by Kukulska-Hulme (2010) but with greater emphasis on the rich and varied resources and social networks now available to learners and how these may shape their learning. Language learners have unprecedented access to authentic language content, native speakers and all manner of language learning materials that were previously out of reach. Popular, freely available resources for language learning include websites, podcasts, mobile apps and open content repositories. When combined with social networks, these represent an enormous resource for the development of language skills, although due to difficulties in identifying and accessing appropriate material and support, many learners will experience considerable frustration (Kukulska-Hulme and de los Arcos 2011).

Faced with such unorganized abundance, learners will often look for more structured environments and some degree of guidance. Ordinarily this is offered via courses of study, whether teacher-led or self-administered. In recent years, a number of online learning communities have become available where language learners can join others in a semiformal environment that provides some structure but also gives them a degree of freedom and choice. One such online language learning environment is 'busuu' (www.busuu.com), which provides a gamified learning experience in a large worldwide community of learners. Apart from working through learning materials and exercises, users also give feedback to other learners. They can set themselves long-term and short-term goals and they receive various rewards that are helpful in maintaining their motivation. They can do all this at a fixed computer or on their mobile device. The emergence of informal yet structured environments such as busuu raises the question of how such environments fit into a broader ecology of language learning opportunities and resources available through mobile learning. The next section describes a study in mobile innovation to support social inclusion and context-specific language development of one particular target group who are already users of services such as busuu – migrants in European cities.

Informal Language Learning in the City: Crossing Boundaries

Large cities attract migrant populations for whom rapid and tailored language learning is a vital aspect of social and economic integration. The MASELTOV project (www.maseltov.eu) is in the process of developing a suite of context-aware smartphone services to assist migrant populations in a number of cities across Europe with daily tasks such as navigation around the city and communicating in the local language. Target learners are immigrants with a relatively low educational level and a cultural background distinct from the host country. In this social inclusion project, the author and her colleagues are working towards defining an 'incidental learning framework' (Kukulska-Hulme et al. 2012; Gaved et al. 2013) to represent a new ecology of activities, resources and human networks in a future-oriented smart city setting where language learning is interwoven with other daily tasks and travel around the city. Incidental learning is traditionally understood as learning that is unintentional or unplanned and that results from other activities (Kerka 2000). In second language acquisition research, incidental learning has been explored mainly in vocabulary-learning studies showing that the activity of casual reading can increase vocabulary size, particularly if certain techniques are applied including dictionary lookup; there is a focus on the relationship between form and meaning and revision after reading (Hulstijn 2003, 2012). This suggests that certain planned strategies can increase incidental learning; it is almost a case of developing good habits to encourage incidental learning. The use of mobile technologies reinforces this, in that unintentional or unplanned learning is, paradoxically, more or less expected when learners are out in the world where anything can happen; therefore, new linguistic and cultural encounters should be factored into the learning experience.

The work on MASELTOV is informed by previous learning models and frameworks including Kearney et al. (2012), Kukulska-Hulme (2012), Park (2011), Luckin (2010) and Sharples et al. (2007), which consider the learning process in relation to various actors, resources and tools available in technology-enabled environments where learners are increasingly responsible for their own learning. The framework we are developing currently envisages a cyclical process whereby learning takes place in the course of daily activity typically beginning with preparation at home, followed by learning while travelling and walking in the city, and a subsequent period of reflection and consolidation when more structured or playful learning can take place on the way home and at home, with family members or friends playing a part. Regular journeys between the home and the city centre create multiple learning opportunities: Language can be rehearsed in preparation for an event, new vocabulary and phrases can be noticed and recorded, and there is a chance to make contact with volunteers, mentors or fellow immigrants who are willing to help. The framework draws attention to the fact that from a learning perspective, we need to design services that are task-focused, that give access to social support and that help learners achieve outcomes that they value; we are also doing additional work on feedback and progress indicators which will help sustain the learning over longer periods of time. Therefore we take into consideration the place and time when learning incidents occur, the tasks that learners are carrying out and their intended outcomes, tools that can be used and any social support available. Situations that require an immediate response can be interspersed with more leisurely planning, structured learning and reflection, each of which may be triggered by the mobile services offered by MASELTOV. More detailed accounts of the incidental learning framework and the project's progress may be found in Gaved et al. (2012) and Kukulska-Hulme et al. (2012) and in the deliverables on the project website.

One of our ambitions is to design target language support and learning services that take account of typical tasks and situations while also being responsive to unexpected incidents that may challenge the learner. Examples of unexpected incidents are having to interpret a notice stating that due to train service disruption, passengers are requested to board a specific bus instead, or arriving at a library and finding a notice stating that due to flood damage, the library is temporarily closed but an information service is available elsewhere. The support tools and services will integrate new tools such as TextLens which uses a phone's camera to recognize a text such as a sign or a notice (Neumann and Matas 2012) and enables quick translation in situ. However, such tools have limitations and there are occasions when human support is needed. Project partners include three non-governmental organisations (NGOs) that provide services to migrants in Austria, Spain and the United Kingdom; these organisations are our gateways to networks of staff and volunteers who can arrange social support for migrants. In the above scenarios, the migrant might take a photograph of a notice and post it to a social forum to get an explanation, or there could be a facility to call a volunteer who speaks one's native language and they might explain that it is quite common for a bus service to be provided when a train is not available.

Through a series of workshops, interviews and focus groups, the needs of several target migrant groups have been identified, from practical tasks such as finding a home and a job, to breaking out of the closed circle of one's own community. The project has also identified the risk of oversimplification of foreseeable situations for which assistance can be provided, since the lives and situations which migrants face are complex. As noted by Ros (2012), any tools provided need to be adaptable, so that they may be appropriated and enriched by the users themselves.

The project's overall aim is to facilitate social inclusion by using ubiquitous technologies to support migrants as they undergo fundamental changes in their socio-economic contexts, when they have to re-establish themselves in a new society, understand a new language, a new culture and a new way of living. Support for the development of target language skills is an essential component of social integration. However, Tammelin-Laine et al. (2013) draw attention to the fact that for those who do not have adequate literacy skills in their first language, acquiring another language in a new country presents a special challenge. In such cases, less formal learning arrangements may be required. An account of successful projects funded through the European Commission's Lifelong Learning Programme highlights the Language Café (established in libraries, cafés and restaurants) as having benefitted people without easy access to language learning or who lacked the confidence to join a formal class, including immigrants (European Commission 2010).

As well as crossing physical boundaries within cities that may tacitly exclude people from certain areas because they do not feel able to go there, migrants are faced with cultural differences that present additional boundaries. The MASELTOV project is exploring game-based approaches to supporting shifts in cultural awareness and is setting up social networks to facilitate peer problem-solving and further exploration of cultural issues. It is hoped that by getting people involved with truly engaging and helpful informal language learning on their mobile phones, some of them will also decide to take up formal language lessons, to improve their grammar and accuracy and to develop more advanced skills in communication and interpretation.

Conclusion

Informal, incidental learning can be seen as a transitional route into formal study and a complementary as well as an alternative mode of learning. Mobile learning is not only a helpful means of learning a foreign language, but as has been argued in this chapter, it is also a lens with which to view language usage and an instrument that can change its use. Digital and mobile media are changing and extending language use to new environments as well as creating opportunities to learn languages in different ways. With increasing application of personal mobile technologies in informal language learning, migrants, students, employees and other learners may begin to explore more readily how they may become agents of change in the landscape of emerging language learning services and resources.

Convention holds that having a conversation in a foreign language is more difficult than reading and writing, and indeed this should not be understated, but new means of supporting conversations may overturn this in time. More exposure to fragments of conversational foreign language usage, together with the possibility of gaining immediate support, may well become a new bridge to language learning, although there is more work to be done in shaping how this will happen. Mobile technologies enable us to get physically closer to social contexts of language use, which will ultimately influence the ways that language is used and learnt.

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Chapter 15
What Seams Do We Remove in Learning a Language?–Towards a Seamless Language Learning Framework

Lung-Hsiang Wong, Ching Sing Chai, and Guat Poh Aw

Abstract This chapter reviews the current notion of seamless learning and language learning theories to guide the development of theory for seamless language learning (SLL). Building on the sociocultural perspective of language learning, which also undergirds the notion of seamless learning, we created a synthetic SLL framework. The framework may leverage the affordances of mobile technology to foster language learning that weaves through different learning spaces, thereby helping language learners to connect the inputs and outputs through meaningful contexts. By doing so, we hope to shed light on what would be the intersection between the language learning theories and the general characteristics of seamless learning, thereby facilitating a dialogue between the two fields. We then analyse prior studies on SLL through the lens of the SLL framework and identify the research gaps. Subsequently, we put forward an instantiation of the framework – an SLL environment known as MyCLOUD (My Chinese Language ubiquitOUs learning Days) – and elucidate how the learning design is informed by the framework.

Introduction

Ever since the notion of seamless learning was introduced into the mobile learning field in 2006 (Chan et al. 2006), the majority of the relevant expositions and interventionist studies have centred on mobile-mediated in-context and cross-context learning. In particular, interventionist studies that are based on specific subject domains tend to treat seamless learning as an extension of single-context, episodic mobile learning designs as posited in earlier literature. Studies in seamless language

L.-H. Wong (✉) • C.S. Chai • G.P. Aw
National Institute of Education, Nanyang Technological University,
Nanyang Walk, 637616 Singapore, Singapore
e-mail: lhwong.acad@gmail.com

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learning, for instance, typically foreground the (re)designs of mobile affordances in supporting specific language learning tasks in multiple learning spaces. Whereas the salient features of general seamless learning are duly instantiated, the use of mobile technology is not conceptualised as day-to-day tools to be rooted in the learners' learning ecology. In addition, the theoretical frameworks behind these seamless learning process designs are often not meticulously established and not rigorously linked to existing language learning theories.

This chapter aims to go beyond the existing learning technology-oriented and especially mobile learning-centric elucidation of seamless language learning by integrating the perspectives of language learning theories and practices as the starting point in investigating and positing the nature of seamless language learning (SLL). An SLL framework is developed as our initial effort in modelling and providing a theoretical framing to SLL. The SLL framework is positioned both as a design framework (to guide researchers and practitioners in designing SLL learning environments) and a learning framework (to inform individual learners in practising SLL). At present, our SLL framework is specifically formulated to address the limitations of common practices in second or foreign language teaching and learning, where learners typically lack authentic environments in their daily life for them to apply and reflect upon the target language. After unpacking the characteristics of SLL, we will proceed to explicate the ultimate goal of language learning in the twenty-first century – to develop learners' language literacy as situated social practice – and how SLL may become a viable vehicle to achieve the goal. Upon doing so, we hope to shed light on what the intersection between the language learning theories and the general characteristics of seamless learning would be, thereby facilitating a dialogue between the two fields. Indeed, we foresee the potential of the notion of SLL in restructuring and refining, if not revolutionising, general language pedagogy and language learning.

Literature Review

Limitations of Traditional/Current Language Learning Practices

While nonacademic factors such as family environment and the lingua franca of the society that a child is situated in inevitably affect her/his motivation in language learning, there is little doubt that language classroom practice plays a crucial role in shaping or reshaping her/his habit of mind in learning (and consequently her/his language competencies). According to our literature review, class observations and teacher/student interviews over the years, the current traditional K-12 language classroom practices (especially in second language (L2) classes in Singapore) typically fall short in the following interrelated aspects:

- Incorporating excessive amount of decontextualised information in teaching: 'second-hand experiences' confined within the classroom (e.g. Jiang 2000; Kumaravadivelu 1999; Tedick and Walker 2009).
- Unbalanced instructional or learning emphases (e.g. Liu et al. 2006; Pica 1994): greater foci on teacher instruction over learner interactions, on language knowledge (or symbolic knowledge) over language skills (or functional knowledge) and on language input over language output activities.
- Reductionist (i.e. knowledge and skills can be decomposed into isolated basic elements and be transferred separately to learners), compartmentalised instructions of language knowledge/skills (Kumaravadivelu 1994): vocabulary knowledge and grammar rules and listening, speaking, reading and writing skills are usually taught and practised separately;
- Exercising the PPP procedure (presentation, practice, production) (e.g. Biggs 1987; Long and Crookes 1991) in a linear fashion, which could be seen as a reinforcement of transmissionist and behaviourist approaches – treating language output activities as the 'consequence' of language input activities and form-focusing before meaning-focusing.
- Lack of promotion of autonomous learning (e.g. Dam 1994) and authentic social interactions within and beyond the classroom.

Scholars have argued that such classroom practices are not conducive to developing learners' communicative skills and elevating/sustaining their learning motivation (e.g. Finch and Sampson 2001; Liu et al. 2006). The instruction tends to be controlled and 'mechanical'. It lacks the liveliness to engage students. To overcome these limitations, researchers and practitioners have been developing innovative teaching and learning activities. Most of these are nevertheless episodic and likely non-sustainable, addressing isolated language learning aspects such as vocabulary retrieval/retention, oral practice, etc. They also tend to overemphasise but not go beyond the fun factor to address the motivation issue.

From Second Language Acquisition (SLA) to Task-Based [Language] Learning (TBL)

Earlier SLA research was largely undergirded by psycholinguistic and/or cognitivist/developmental perspectives, with Krashen (1982) proposing the monitor model in the midst of growing dissatisfaction with the behaviourist approach. One of the most referenced hypotheses in this model is the comprehensible input hypothesis, which expounds how acquisition occurs when one is exposed to language that is comprehensible and that contains $i+1$ – the 'i' represents the level of language already acquired, and the '+1' is a metaphor for language that is just a step beyond that level.

Many researchers challenged Krashen's model (e.g. White 1986) on the ground of whether input is a sufficient condition for language acquisition. Henceforth, Swain (1985) proposed the comprehensible output hypothesis by asserting that the relevant, therefore comprehensible input and output produced during interaction push learners to work not only syntactic structure but also the meaning of their and their partners' utterances, which might result in language acquisition. Similarly, Long's (1983) interaction hypothesis argued that what learners need is not necessarily simplification of the linguistic forms but rather opportunities to interact with other speakers, working together to reach mutual comprehension with modified input. A more refined version of this hypothesis (Long 1996) was extended to take into account corrective feedback, clarification, comprehension check and negotiation of meaning, as the factors contributing to L2 acquisition. In short, the $i+1$ model seems too simplistic, and theorists are considering many more language acquisition mechanisms from an interaction perspective.

Since the mid-1990s, the field of SLA has been trying to go beyond the cognitive-interactionist framework (e.g. Firth and Wagner 1997; Hall 1993; Lantolf 2000). Attuning to the spirit of the times, the new social perspectives (in particular, the Vygotskian sociocultural perspective) advocate that cognitive development, including language development, arises as a result of social interaction. Unlike the psychological-individual perspective that viewed thinking and speaking (or language production in general) as related but independent processes, sociocultural theory viewed language production and thinking as tightly interwoven. Language production mediates thinking, i.e. people can gain control over their mental processes as a consequence of internalising what others communicate to them and what they communicate to others (Lightbown and Spada 2013). The reorientation towards the fundamental role of social processes in SLA had shed light on deriving new frameworks to reconceptualise earlier SLA hypotheses.

For example, using the term 'collaborative dialogues', Swain and Lapkin (2000) carried out studies to determine how learners co-constructed linguistic knowledge while engaging in production tasks that simultaneously drew their attention to form and meaning. They considered collaborative dialogues as the context where language use and language learning can co-occur. 'It is language use mediating language learning. It is cognitive activity and it is social activity' (p.97). Similarly, Ellis and He (1999) posited that it is not appropriate to talk of input and output separately in the sociocultural perspective; one has to consider interaction as a totality, a matrix in which learning is socially constructed. Indeed, in Vygotskian theory, greater importance is attached to the conversations themselves, with learning occurring through social interaction (Lightbown and Spada 2013). Participation in social activities is the primary goal of the subject, and the learning of language occurs naturally to fulfil the primary goal.

A related development during the same period of time was the growth of task-based language learning (TBL) (Willis 1996) to address the limitations of the PPP model as demonstrated by SLA research in mid-1980s. Skehan (1996) defined tasks as activities which have meaning in their primary focus. He summarised the contrast between the two constructs: 'A PPP approach looks on the learning process as learning a series of discrete items and then bringing these items together in communication to provide further practice. A task-based approach sees the learning process as one of learning through doing – it is by primarily engaging in meaning that the learner's system is encouraged to develop' (p. 21).

To facilitate TBL, Willis (1996) developed a framework that defines a three-stage activity sequence (pre-task, task cycle and language focus) with a striking feature of form-focused activities occurring after students' enactment of a meaning-focused task. This is a major departure from the PPP model where the presentation and the practice of linguistic forms come before the meaning-making production activities. Moreover, during the enactment of the task itself, the teacher monitors and encourages attempts to communicate meaning in the target language and does not correct errors – the emphasis is on spontaneity and fluency. This challenges a common perception among language teachers (according to our interactions with language teachers and our class observations over the years) that errors are 'evil' and must be immediately rectified. In addition, proponents of TBL have argued for the importance of incorporating authentic activity that reflects real-world contexts, i.e. to achieve situational authenticity. However, there are many learning tasks which are patently not real world, e.g. telling a story based on a picture. Such tasks do correspond to the kind of communicative behaviour that arises from performing real-world tasks, as the participants will need to negotiate their way to shared understanding by asking questions and clarifying meanings. This is known as interactional authenticity (Ellis 2000).

Researchers had been attempting to theorise TBL in both psycholinguistic and sociocultural perspectives. The psycholinguistic perspective of TBL draws on a computational model of SLA (Lantolf 1996) where tasks are viewed as devices that provide learners with the data they need for learning. According to Yule (1997) and Ellis (2000), the inherent weakness of this approach is the over-focus on attributing learning outcomes to inherent task properties (i.e. the task design itself) without the consideration of other general spontaneous factors (e.g. actual classroom conditions, varied enactments among student groups, etc.). Conversely, the sociocultural perspective claims that participants always co-construct the activity they engage in, in accordance with their own socio-history and locally determined goals. Hence, the same task design can result in very different kinds of activity/enactment when performed by the same or different learners at different times (Ellis 2000). Learning arises not *through* interaction but *in* interaction. Learners first succeed in performing a new function with the assistance of another person and then internalise this function so that they can perform it unassisted – i.e. they are in the zone of proximal development (ZPD) (Vygotsky 1978), with the new functions 'scaffolded' by the participants.

In a nutshell, the evolutions of SLA and TBL see the following prominent, often recurring, principles of language learning being put forwards:

- Learning by doing (language applications) (Ellis 2000; Skehan 1996).
- Create opportunities for social interaction among learners (Long 1983, 1996).
- Interweave language input and output activities (Ellis and He 1999; Long 1983, 1996; Min 2006).
- Incorporate situationally or interactionally authentic learning activities (Ellis 2002).

- Simultaneously draw learners' attention to form and meaning, or even be meaning-focused before form-focused (Swain and Lapkin 2000; Willis 1996).
- Assist learners in gaining control of their cognitive process as a consequence of internalising the social activity and peer scaffolding (Lightbown and Spada 2013).
- Facilitate learners in co-constructing linguistic knowledge, or even co-constructing activities (Ellis and He 1999; Swain and Lapkin 2000).
- Integrate, rather than isolate, language skills development (Kumaravadivelu 1994; Skehan 1996; Willis 1996).

The TBL paradigm inherently encompasses all these principles. However, in practice, individual TBL processes (e.g. those adhering to Willis' three-stage activity sequence) still tend to be episodic, self-contained, typically confined within the classroom and predominantly teacher-facilitated (i.e. little learner autonomy despite being learner-centred). The situational and interactional authenticity of the episodic events may need constant renegotiation between the teachers and learners since the teachers assume much responsibility in planning the task. In addition, the links between tasks may not be strong enough to foster a habit of mind for language learning beyond the TBL activities.

Mobile Seamless Learning (MSL)

Chan et al. (2006) characterised mobile-assisted seamless learning (MSL) as a learning approach where each learner who has 24/7 access to at least one mobile device (1:1) would have plenty of opportunities to learn across various learning spaces – thus affording individual learners a genuinely holistic and perpetual learning experience. Research in MSL has been gaining momentum over the years. However, as the majority of the studies were conducted in the context of learning technology (rather than learning sciences), the research inquiries largely rest on technological innovations, specific pedagogical solutions and/or operational frameworks for launching or scaling up 1:1 MSL initiatives in school contexts.

As part of the ongoing effort to advance MSL into an established learning approach, Wong developed a characterisation model, '10 dimensions of MSL' (10D-MSL) (Wong 2012; Wong and Looi 2011). With the model, Wong underlined the salient feature of MSL that distinguishes it from other learning approaches – not just learning anytime, anywhere, but *bridging* the learning experience and learning gains across multiple learning spaces and bringing together the originally compartmentalised learning efforts of an individual learner. Furthermore, drawing on the notions of 'mediation by artefacts' (Vygotsky 1978) and distributed cognition (e.g. Hatch and Gardner 1993), Wong et al. (2012b) developed the 'artefact-oriented analysis' method to describe the spontaneously holistic natures of cross-space MSL activities. According to such a perspective, learners co-construct a learning activity on the fly by combining available human, tangible and non-tangible resources ('mediating artefacts') in a particular learning space. The outcomes of the learning activity (e.g. specific learner's artefact, the experience or the skills gained, etc.) may be carried over to another learning space to mediate subsequent learning activities.

All these explications of MSL are pointing to the sociocultural nature of the learning approach. Practising MSL can be seen as putting individual learners into the sociocultural space. In this perspective, MSL embraces socio-constructivist and autonomous learning. Learners are no longer passive 'consumers' of externally facilitated learning contexts (e.g. textbooks, teacher-structured tasks, cultural locales that learners visit, etc.) but active 'manipulators' of their living spaces by incorporating those learning resources into their personal (or social, if they involve other people situated within those spaces, e.g. peers within the class, family members, museum guides, etc.) learning environment. For a seamless learner, to bridge the learning process across spaces is to continually reconstruct his/her learning contexts and the meaning that he/she has made (Sharples et al. 2009; Song et al. 2012).

Notwithstanding, to become a genuinely autonomous seamless learner is a tall order for learners who are more accustomed to the present transmissionist education system. Henceforth, Wong (2013b) envisaged the enactment of long-term, cyclic and systematically varied facilitated seamless learning (FSL) to progressively transform learners' beliefs about learning and enculturate them in the new learning approach. The keyword here is *enculturation*, defined by Kelly (2001) as 'the process of a culture (one's environment and all it includes) shaping and influencing who we are and how we look at the world'. As with most of the other interventionist studies in the field of learning sciences, the ultimate aim of promoting seamless learning is to reshape the learning culture in the schools and in individual learners. The FSL framework is aimed to inform researchers and practitioners on MSL process design and analysis.

Towards a Seamless Language Learning (SLL) Framework

In this section, we present an SLL framework grounded in the sociocultural intersection of language learning theories and the seamless learning notion, informed by the designs and research outcomes of our previous SLL projects in Singapore, with primary school students (grades 3–4) studying Chinese as a second language (Wong 2013a; Wong et al. 2010, 2012a). Our aim is to refine models and theories for language learning or seamless learning leveraging, rather than driven by emerging technological affordances. We foresee the potential of this framework to be further developed into a rigorously theorised language learning approach in the long run. Thus, the SLL framework is positioned both as a design framework (to guide researchers and practitioners in designing SLL environments) and a learning framework (to inform individual learners in practising SLL). Just like TBL, the SLL framework does not prescribe specific learning activities. In its place, a set of salient characteristics are put forward here to conceptualise SLL. Moreover, the conceptualisation here does not explicitly factor in the mediation of the mobile/digital technology but rather focuses on the language learning practices themselves.

First of all, SLL is a domain-specific form of the general seamless learning framework. It therefore inherits the primary objective of the latter – the *bridging* of the originally compartmentalised learning efforts of a learner. In this regard, the SLL framework encompasses the following six learner-centric MSL characteristics as specified in the 10D-MSL model (Wong and Looi 2011), namely:

(SL1) Across time
(SL2) Across locations
(SL3) Encompassing formal and informal learning
(SL4) Encompassing physical and digital worlds
(SL5) Encompassing individual and social learning
(SL6) Knowledge synthesis (combining prior and new knowledge and multiple levels of thinking skills – i.e. from abstract to concrete knowledge; the exercise of lower- to higher-order thinking skills)

If we loosely associate these characteristics with the major language learning principles informed by both the SLA and TBL framework, characteristics (SL1)–(SL4) imply the incorporation of situated and authentic learning as crucial elements of language learning. In other words, language learning should traverse time, location, formal and informal learning spaces and physical and digital worlds. Language learning should also be anchored to social interactions and personal reflection as coupled means to facilitate or scaffold individual learners in gaining control of their cognitive processes (i.e. SL5). Furthermore, language learning calls for knowledge and skills integration in language teaching and learning (i.e. SL6).

How would the four key concepts of seamless learning, namely, bridging/interweaving multiple learning constructs, authenticity, interaction-reflection and knowledge/skills integration, be schematically incorporated into language learning practices? The following salient features specific to language learning are distilled:

(SLL1) Create opportunities for situationally/interactionally authentic activities among learners (and perhaps among learners, their family members or other community members, etc.), within and beyond the classroom.
(SLL2) Interweave language input and output activities.
(SLL3) Interweave learning of linguistic knowledge, application and reflection process – learning by doing and learning by reflection – and the process should be non-linear and recursive.
(SLL4) Simultaneously draw learners' attention to form and meaning, or even being meaning-focused (to achieve linguistic fluency) *before* being both form- and meaning-focused (to achieve linguistic accuracy, contextual [meaning] appropriateness and both contextual and linguistic complexity).
(SLL5) Engage learners in activities that apply multiple language skills in different combinations.
(SLL6) Promote learner (or learners, their family members, etc.) co-construction of linguistic knowledge and perhaps even learning activities (congruent to the notion of 'learner context generation' (Luckin 2008; Wong 2013a)).

Although the above-stated principles of SLL bear some resemblance to those of TBL, SLL builds on the underlying theories and design principles of TBL but not its actual activity process. Unlike TBL, the SLL learning journey is technologically mediated, cyclical, perpetual, open-ended and socially co-owned and co-constructed by teachers and learners. It may consist of interwoven learning tasks/activities, either facilitated by the teachers or self-initiated (by the learners) and either planned or incidental/emergent. It serves as a means to embed language learning into daily life and create situationally or interactionally authentic contexts for learning – not confined by the space (e.g. classroom, e-learning portal) or the time (e.g. class hours, the duration of a single TBL process) of learning. However, it is more than just learning anytime, anywhere – it involves the conscious bridging of originally compartmentalised learning constructs, learning activities and learning gains.

With the refutation of the reductionist view of language learning in mind, a radical revision of the domain-specific learning objective of SLL is inevitable. In the end, what all language learning activities are intended to account for is to develop learners' language literacy. Current research defines literacy not just as the multifaceted act of reading, writing and thinking but as constructing meaning through language artefacts within a sociocultural context (Erickson 1984; Gee 2000; Street 1995). Such a perspective rejects the view that literacy consists of decontextualised linguistic skills and that becoming literate requires the learning of discrete skills. Instead, it gives way to a more functional, constructivist and culturally relative view of literacy as situated social practice. In an increasingly pluralistic society, it is important to recognise that literacy is not an autonomous cognitive practice but an interactive process where talk and language artefacts play a significant role in defining and negotiating meaning as readers and writers transact (communicate) with the semiotic artefacts in a sociocultural environment (Pérez and McCarthy 2004).

To this end, we see the need to reposition the language learning objective in the context of SLL. Chen et al. (2011) proposed a two-dimensional framework for new media literacy, with one axis specifying functional literacy (the ability of comprehending media content and creating media content utilising technology) vs. critical literacy (the ability of analysing, evaluating and critiquing media) and another on consuming literacy (the ability to access a media message and use it in different levels) vs. prosuming literacy (i.e. consuming + producing; the ability to access, analyse, evaluate and communicate a message in a variety of forms). In Singapore, for example, we argue that most of the K-12 students' Chinese language competences have not even satisfyingly reached the functional literacy level (while their prosuming literacy is weak as well) but merely at the level of compartmentalised language knowledge/skills that is just adequate to get a reasonably good grade at the formal examinations. Confining language learning to the traditional mode anchoring around examinations could be the primary reason why students feel that language learning is artificial, repetitive and boring. We argue that it is necessary to repurpose the learning of language as acquiring the means to be a functional and productive member in a community. For the twenty-first-century learners dubbed as digital natives, this means forming blended communities where language artefacts are shared to achieve social purposes. This in turn would mean that learners need easy access to tools for speedy production of artefacts.

Hence, depending on the length of intervention and the learners' age group, the learning objective of SLL should be focusing on nurturing learners' functional-prosuming literacy or critical-prosuming literacy, though with a greater focus on the linguistic (rather than the full multimodal) elements of the media that they are 'prosuming'. In this aspect of learning assessment, although we do not condemn the evaluation of discrete skills (e.g. vocabulary, oral or writing skills), greater emphasis should be placed on assessing the learners' holistic language development based on the new perspective of literacy.

In addition, due to the continual (perhaps longitudinal), complex and open-ended nature of the learning journey of SLL, we advocate formative assessment on the artefacts and/or recorded social interactions of the learners over time as the predominant method of evaluation. Peer reviews on the collections of the learner artefacts can be carried out so that learners with varied competencies and life experiences can bring in different perspectives to advance their learning.

In this regard, an additional salient feature of SLL is formulated as below:

(SLL7) Emphasise formative assessment and peer evaluation on learners' holistic language development or literacy level.

Prior Seamless Language Learning Research

To understand the state of play of MSL, we performed a literature scan to identify publications between 2006 and 2013 on intervention studies where the authors explicitly characterise their work as MSL. Among the 40 MSL projects with specific target domains, language is the second most popular subject category being studied (9 projects; after natural science with 10 projects). Tables 15.1 and 15.2 provide a summary and our analysis of the 9 SLL projects. Note that the rightmost column in Table 15.2, 'SLL7', refers to the means of learning assessment embedded into the learning process itself. Some studies did not incorporate language learning assessment as part of their learning designs and instead administered pre- and posttests merely for the purpose of quasi-experimental research analysis – those are considered as interventionist designs *without* assessment components.

According to our literature scan, there seems to be an increase in mobile-assisted language learning (MALL) studies which are explicitly positioned as SLL by researchers since 2011. This is probably because the general MSL as a line of research has been gaining momentum and exposure in recent years, thanks to the proliferation of mobile technology, and more MALL researchers are therefore seeking to employ the learning approach to inform their techno-pedagogical designs. Furthermore, a promising observation is that all but one of these projects were designing for SLL practice beyond one-off or episodic periods and instead either facilitated ongoing interventions ranging from 1 to 10 months or developed

Table 15.1 Summary of the nine SLL projects reported in the literature (2006–2013)

Project title and citation(s)	Target learners/target language/ target language skills	Intervention design	Theoretical grounding
Context-aware u-learning environment (Yang 2006)	Not specified/English *[in the prototype]*/reading; text chat interactions	A context-aware ubiquitous learning (u-learning) environment was developed. Significant features include context awareness, learner modelling, personalised annotations on Web resources, matchmaking of peers with similar interests and real-time discussions. The system is domain independent, but the prototype reported is for English learning	(Not specified)
LOCH (Ogata et al. 2008)	College/Japanese as foreign language/oral interactions	Guided by a PDA application, individual learners carry out authentic conversational tasks with native speakers. Afterwards, learners return to the classroom for a teacher-facilitated reflection session. This is a one-off learning process design	Authentic language learning
'Move, Idioms!' (Wong 2013a; Wong et al. 2010, 2012b; Wong and Looi 2010)	Grade 5/Chinese as L2/ vocabulary (idioms and conjunctions) and writing	In learning Chinese idioms and conjunctions, students proactively use smartphones on a 1:1 basis to capture photos of the real-life contexts pertaining to the idioms and to construct sentences with them. Subsequently, in-class or online sharing and discussions on the contexts take place, which would enhance the students' understanding of the proper usage of the target vocabularies. The intervention lasted 10 months	Nation's (2001) three psychological stages for vocab. learning/language learning by situated and social meaning making/learner-generated contexts

(continued)

Table 15.1 (continued)

Project title and citation(s)	Target learners/target language/ target language skills	Intervention design	Theoretical grounding
SCROLL (Ogata et al. 2011)	Not specified/any language/ vocabulary	A u-learning system was developed for learners to log (and share with peers) day-to-day learning experiences in the form of geotagged, multimodal learner artefacts ('ubiquitous learning log objects' or ULLO). The system may automatically link similar ULLOs to become a knowledge structure and generate quizzes to reinforce a learner in their previously learnt knowledge. A prototype reported is for vocabulary learning (with learner created photo-vocabulary pairs as ULLOs)	Incidental vocabulary learning
Vocab Challenge (Redd and Schmidt-Crawford 2011)	Grades 10–11/English as L1/vocabulary	Learners are using iPod Touch to play with the Vocab Challenge app at their own convenience for a period of three weeks. The game involves learners working with a particular vocabulary until mastery – occurring through correct answers on the synonym, antonym, connotation and definition quizzes	Game theory/information processing model/vocab. pedagogies

'WE Learn Project' (Koh et al. 2013; Koh and Looi 2012)	Grade 3/English as L1/vocabulary	It was a 2-week teacher-facilitated lesson unit focusing on vocabulary learning as part of a longitudinal mobilised English language curriculum. The cross-contextual learning flow was comprised of: (1) students noticed, audio-recorded and checked e-dictionary on new words in a story that the teacher read aloud; (2) students made sentences in and out of class utilising teacher-specified words; (3) students took pictures or sketched images to demonstrate tenses and metaphors pertaining to specific words; and (4) students identified and classified antonyms of the learnt words	10D-MSL
'Growing Up' (Wei 2012)	Workplace/English as foreign language/text chat interactions	An online learning community based on QQ (China's version of MSN) was established as an extension of the English language course within a police academy. Students and teachers communicated through the QQ Group (accessible by their mobile devices and laptops) in English for resource sharing, group chat, reflection and self-/peer evaluations. The experiment was carried out for 4 months	Autonomous language learning/ theory of immediacy behaviours

(continued)

Table 15.1 (continued)

Project title and citation(s)	Target learners/target language/ target language skills	Intervention design	Theoretical grounding
SMALL (Uosaki et al. 2012)	College/English as foreign language/vocabulary; reading	A system was developed for vocabulary learning through reading. Individual learners maintain their own word lists in the form of the set of photo-and-vocabulary or sentence-and-vocabulary ULLOs (see the description of SCROLL in this table). New personal ULLOs are created through clicking on words appearing in e-textbook passages or adding words incidentally learnt in daily life. Learners may also study and compare peer-created ULLOs pertaining to the same word	Vocab. learning by form-meaning connection in multiple contexts
ULa Lab (Chong and Gaol 2013)	Not specified	A ubiquitous open content Web-based language lab was developed. The system is accessible by a variety of mobile devices for teachers and students to create and share multimedia language learning resources and carry out certain language lab activities online	Authentic learning/situated cognition

Table 15.2 Analysis of the nine SLL projects reported in the literature (2006–2013)

Project title	SL1	SL2	SL3	SL4	SL5	SL6	SLL1	SLL2	SLL3	SLL4	SLL5	SLL6	SLL7
Context-aware u-learning	Yes	Yes	Mainly informal	Digital only	Yes	Not explicit	Yes	Not explicit	No	Not explicit	Not explicit	No	No embedded assessment
LOCH	One-off	Yes	Yes	Yes	Mainly social	Not explicit	Yes	Yes	Yes	Yes	No	Not explicit	In-class reflection as formative assessment (on oral skills only)
SCROLL	Yes	Yes	Mainly informal	Yes	Mainly individual	Yes	Yes	No	Not explicit	Yes	No	No	Simple quizzes (on vocab. only)
'Move, Idioms!'	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not explicit	Yes	Peer reviews as formative assessment (on vocab. and writing)
Vocab Challenge	Yes	Yes	Mainly informal	Digital only	Individual only	Not explicit	No	Input only	No	No	No	No	The game itself as an assessment (on vocab. only)
'WE Learn Project'	Yes	Yes	Yes (more towards formal)	Yes	Yes	Not explicit	Yes	Yes	Yes (less emphasis on reflection)	Yes	Yes	Not explicit	No embedded assessment
'Growing Up'	Yes	Yes	Yes (more towards informal)	Digital only	Mainly social	Not explicit	Yes	Yes	Not explicit	No	No	Not explicit	Teacher and peer assessment (but not clear on which aspects to assess)
SMALL	Yes	Yes	Yes	Digital only	Yes	Yes	No	Input only	Not explicit	Yes	No	No	System-generated quizzes (on vocab. only)
ULa Lab	Yes	Yes	Yes	Digital only	No	Not explicit	Yes	Yes	Not explicit	Not explicit	Yes	No	No embedded assessment

Note: *(SL1)* across time, *(SL2)* across locations, *(SL3)* encompassing formal and informal learning, *(SL4)* encompassing physical and digital worlds, *(SL5)* encompassing individual and social learning, *(SL6)* knowledge synthesis, *(SLL1)* opportunities for situationally/interactionally authentic activities, *(SLL2)* interweave language input and output activities, *(SLL3)* interweave learning of linguistic knowledge, application and reflection, *(SLL4)* simultaneously draw learners' attention to form and meaning, *(SLL5)* activities that apply multiple language skills in different combinations, *(SLL6)* co-construction of linguistic knowledge, *(SLL7)* formative assessment on holistic language skills technological platforms that afford perpetual, informal learning. A longer-term process of learning is crucial for language learning as the acquisition of language knowledge and skills should be accumulative, spiral and genuinely immersed into learners' daily life. Research in MALL and technology-enhanced learning in general have a long tradition of facilitating rather short-term and intensive experiments, which is perhaps conducive for rigorous control of variables in quasi-experimental settings. Such interventions would however not necessarily result in sustainable learning gains in the long run.

Nevertheless, through our analysis of these learning designs, we argue that this line of research is still at a beginning stage. Most of the SLL studies were conducted from learning technologists' perspective which typically prioritises development or exploitations of mobile affordances. The way that most SLL researchers see how they facilitate seamless learning is often reduced to carrying out language learning activities in both formal and informal settings, across time and locations, and repetitively – but the learning efforts in those spaces are not necessarily *bridged* and connected together. Explicit effort in bridging the activities will help the learners in intentional learning. In addition, some studies are not associated with any language learning theory or loosely related to isolated conceptual arguments or instructional strategies advocated by established language learning scholars. Moreover, some SLL designs have resorted to behaviourist learning or assessment modes with the main objectives of retrieval and retention. In sum, it seems clear that SLL needs more theorising and model building supported by current language learning theories.

MyCLOUD: Our Instantiation of the SLL Framework

To address the gaps we identified earlier and to actualise the SLL framework we delineated, we have obtained competitive funding for a research project MyCLOUD (My Chinese Language ubiquitOUs learning Days). MyCLOUD is a design-based research study with the aim of developing a scalable mobile- and cloud computing-assisted Chinese language (CL) learning environment that is intended to be integrated into the formal curriculum as well as for the enculturation of seamless and autonomous language learners. The environment is set to be scaled up in five Singaporean schools by 2014 where longitudinal MyCLOUD intervention (for all students from primary 3–4/grades 3–4) will take place.

The development of MyCLOUD includes the articulation of the learning design framework and the ensuing technological platform. The platform was informed by our learning process design. It is meant for mediating students' SLL experience – in particular, to reinforce the bridging of individuals' learning experiences across multiple spaces. However, we describe the platform affordances before elaborating on the high-level learning design framework (i.e. a concrete-to-abstract narrative flow) as we believe it will be easier for readers to comprehend how the entire environment works. The platform is comprised of the following major components:

- My Mictionary (我的C动词典): Mictionary refers to mobile dictionary. This is a space where students tag vocabularies that they encounter in and out of class and perform self-directed search for meaning and example uses of the vocabularies. It serves as students' personalised vocabulary learning e-portfolio. Students can expand their own vocabulary bases as well as refine their usage of vocabularies anytime, anywhere, and build contents on individual vocabularies by pooling other relevant online resources or creating/uploading photos/sentences.
- My e-Textbook (电子课本): The textbook articles are digitised and linked to a Web-based text-to-speech service powered by Microsoft Bing for the system to read the articles aloud to the students. Meanwhile, students can highlight unfamiliar vocabularies and conveniently add them to My Mictionary.
- CoMictionary (词语讨论区/'同学们怎么用'): CoMictionary refers to 'Community Mictionary'. The system generates one 'vocabulary page' for each vocabulary added by any student into their own My Mictionaries and consolidates all the artefacts created by different students with the same vocabulary onto one page. This is to facilitate peer comparisons and discussions, thus achieving social generalisation of the contextual application knowledge of individual vocabularies.
- MyCLOUDNet (我的主页): This is a social networking space for students to tweet or update status or carry out informal microblogging (or photoblogging, i.e. photo + sentence), and respond to these tweets, in Chinese. A tweet posted by a student can also be linked to My Mictionary (depending on the vocabulary that she incidentally uses). Students may also carry out peer discussions to improve the accuracy and complexity (linguistically or contextually) of individual artefacts or just casual, socialising interactions. A related system component is a special space for students to write full compositions (either for regular classroom compositions or for self-initiated writing) and share them with their peers.
- My Teaching Pal (教师主页): This is a classroom management user interface for teachers to create learning sessions, send messages to all or selected students, manage the classroom learning flow as well as enable all or selectively limit students' usage of the features on the MyCLOUD platform.

The platform is accessible by both a Windows smartphone app (to carry out simple tasks on the move such as photo taking and sentence making, accessing to My Mictionary, social networking through MyCLOUDNet, etc.) and PC/laptops (for full set of affordances). From individual students' perspective, My e-Textbook and CoMictionary belong to the formal learning spaces, while MyCLOUDNet is an informal learning space. My Mictionary is the means of bridging the two spaces by linking to My e-Textbook, CoMictionary and MyCLOUDNet. If a student creates an artefact and adds it to a vocabulary page in My Mictionary (individual, formal-informal bridging space), the artefact will also be duplicated to both the CoMictionary (social, formal space) and MyCLOUDNet (social, informal space). Two types of peer discussions could emerge – on vocabulary knowledge generalisation/consolidation with multiple student artefacts as resources in CoMictionary and corrective/enriching feedback or socialising interactions on individual artefacts in MyCLOUDNet.

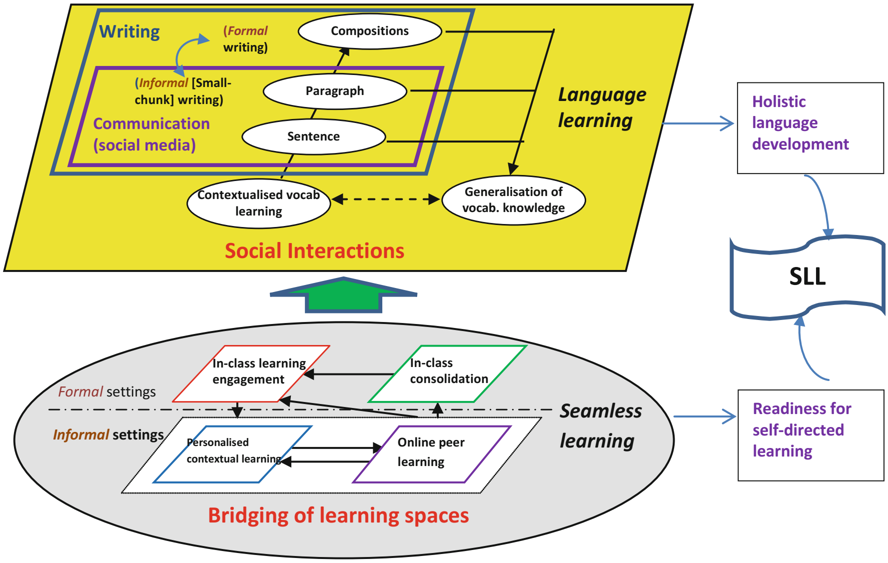

Fig. 15.1 The learning design of MyCLOUD 2

Such discussions can be characterised as social meaning making which may then trigger individual learners' reflections. Teachers are advised to hold back their corrective feedback for a reasonable period of time and instead encourage peer reviews in these discussion threads. Similarly, a student's spontaneous status update (with or without an attached photo) in MyCLOUDNet may be duplicated and stored in her My Mictionary and CoMictionary if she specifies a particular vocabulary that she has incidentally used in the written text.

Figure 15.1 depicts the learning design framework of MyCLOUD. It shows the division of the two intertwining dimensions of seamless learning and language learning. Within the seamless learning dimension, the FSL framework (the cyclic but non-linear process of 'in-class learning engagement', 'personalised contextual learning', 'online peer learning' and 'in-class consolidation') is adopted as the basic learning process to guide the actual language learning activities (see below).

Within the language learning dimension, we are placing the emphasis on holistic language development. Whereas students will continuously carry out cycles of contextualised vocabulary learning (enriching vocabulary entries in My Mictionary) and generalisation of vocabulary knowledge (comparing peer-contributed sentences utilising the same vocabulary in CoMictionary), the writing activities are foregrounded on top of the vocabulary learning cycles. Such activities come in the form of social media-based interactions (through composing sentences and paragraphs and giving comments), which will also be linked to personalised composition writing. Practising writing through composing sentences and paragraphs is known as '小练笔' in the context of CL writing instructions, which literally means 'micro writing (exercise)'. Such an approach is regarded not only as a means to build up linguistic skills in a bottom-up manner but also to reduce students' anxiety in carrying out writing activities in L2. What is unique in the micro-writing activities in MyCLOUD is that they are blended into students' daily life, with the aim of transforming them into self-directed writers. Special software features and teacher scaffolds will be designed to link students' content building for My Mictionary and social networking in MyCLOUDNet (informal writing) into classroom composition (formal writing) and vice versa, thus seamlessly bridging formal and informal writing.

Beyond these platform-based activities (digital space), the habit of mind that we want to nurture in the students is to proactively make meaning and create artefacts arising from their *situationally authentic* experience in daily life (physical space). Informed by the FSL framework, the teachers first organise students to work in small groups during the 'in-class learning engagement' in brainstorming and creating artefacts. It is expected that the ZPD will take effect, where students can learn from each other in the knowledge and skills of artefact creation through peer scaffolding. This is to prepare the students to carry out out-of-school 'personalised contextual learning', where they may work individually or involve their family members or other people in creating more linguistic digital artefacts. Face-to-face verbal interactions (with *interactional authenticity*) will take place in performing such planned or spontaneous artefact creation tasks, often with negotiations of both form and meaning taking place, thus accomplishing language learning gains in a different dimension.

Thus, the entire MyCLOUD learning process design satisfies the first six principles of the SLL framework: creating opportunities for authentic interactions among learners, and among learners and other people (SLL1); interweaving language input and output (SLL2); interweaving learning, application and reflection process – in a non-linear and recursive manner (SLL3); drawing learners' attention to form and meaning (SLL4); learners to apply multiple language skills in different combinations – involving vocabulary, grammar, reading, writing, verbal interactions, etc. (SLL5); and learners to co-construct linguistic knowledge – through social meaning making (SLL6).

With the domain-specific objective of holistic language (or prosuming literacy) development in mind, we are now (by the time this chapter is written) in the process of developing holistic assessment rubrics to formatively track and evaluate the quality of students' artefacts (including both those produced from informal writing [photo/sentences, social networking] and formal writing [compositions] activities) and peer discussions throughout the entire intervention period. The assessment rubrics will be used for holistically evaluating accuracy, complexity and contextual appropriateness/ richness of individual artefacts, as well as for assessing their communicative skills and the comments they provide in MyCLOUDNet and CoMictionary. We will refer to the rich expositions of functional, critical and prosuming literacies in the field of new literacies in setting the concrete criteria and benchmarks for the rubrics. The rubrics will then be validated by involving the participating teachers to ensure their practicality and scalability. We acknowledge the limitation of this prospective assessment construct for only being able to evaluate students' stored digital artefacts and interactions on the platform. The student-group or student-family verbal interactions during the artefact creation processes will be out of the scope of the assessment, though we see the latter as an equally important aspect in the overall learning journey of students using MyCLOUD.

Conclusion
This chapter reviews the current notion of seamless learning and theories of language learning to solicit appropriate theoretical foundations to guide the development of theory for seamless language learning. Building on the socio-cultural perspective of language learning, which also undergirds the notion of seamless learning, we created a synthetic SLL framework. The framework may leverage the affordances of mobile technology to foster language learning that weaves through different learning spaces, thereby helping language learners to connect the inputs and outputs through meaningful contexts. Although the development of the framework was initially motivated by the need to address the limitations of conventional approaches for L2 learning, we see the potential of generalising it to the contexts of L1 learning.

The framework has been instantiated through the MyCLOUD research project. Thus far, this framework has become a means for us to communicate with various stakeholders (funding agencies, school leaders, Chinese language teachers, students and their parents) to convey our theoretical stance and to obtain support for the study. In addition, it has guided many sessions of learning process co-design between the researchers and the teachers. Our initial assessments of students' learning in terms of enhancing their learning performances and fostering students' self-directed and collaborative learning have been positive (Aw et al. in press). However, spontaneous participation and creation of linguistic artefacts could be further promoted, which in turn indicates that further refinement of the framework is needed such that SLL can be deeply rooted in the students' learning ecology.

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Chapter 16
Experiences of Using a Blended Mobile Learning Approach to Connect Classroom and In-Field Learning Activities in a Local Culture Course

Gwo-Jen Hwang and Ju-Ling Shih

Abstract In-field learning activities have been identified as being an important way of helping students connect the knowledge learned in the classroom to real-world contexts. The advancement and popularity of mobile and wireless communication technologies further provide an opportunity to assist students in linking what they have learned in in-field and classroom activities, including their prior knowledge learned from the textbooks and their real-world experiences acquired across time and space. In this chapter, the instructional model and lead-in procedure of conducting learning activities for an elementary school local culture course are reported to demonstrate how mobile and wireless communication technologies can be used to bridge classroom instruction with in-field activities. Some preliminary findings of such a seamless learning approach are also presented and discussed in terms of learning attitudes, self-efficacy, and identification with local culture.

Background and Objectives

As globalization is an obvious post-twentieth-century phenomenon, the social milieu has begun to stress work on localization to preserve and sustain respective cultural and historical inheritances. Taiwan's government also started to promote local culture education a few years ago and requires mandatory education to provide local culture courses in order to nurture students' cultural historical perceptions and interest. Meanwhile, the twenty-first-century skills that students need to possess include global awareness, self-directed learning, information and communications

G.-J. Hwang (✉)
Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taipei, Taiwan
e-mail: gjhwang.academic@gmail.com

J.-L. Shih
Department of Information and Learning Technology, National University of Tainan, Tainan, Taiwan

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technology literacy, problem-solving skills, as well as time management and personal responsibility (Lombardi 2007). The Ministry of Education in Taiwan consequently emphasizes education to explore students' potential working toward self-fulfillment and aims to foster students' abilities to adopt life situations and improve life quality by offering them learning opportunities to experience life, interact with peers and their environment, and construct knowledge. At the same time, students are encouraged to identify with their home cultures and to respect multicultural concepts.

Taking on this perspective, this chapter presents a study of local culture education with an emphasis on exploring historical monuments. Local culture education, in general, emphasizes student-centered learning activities, the main objectives of which are to teach students the ways to think, feel, experience, and discover their living environments and to learn from them. Such courses normally include cognitive, affective, and psychomotor skills education. To facilitate students' in-field exploration of the environment and to effectively monitor individual students' learning progress, using mobile devices to assist the learning process is a new approach that has been adopted in recent years.

With the development and prevalence of information and Internet technology, cases of technology-enhanced learning have been widely seen across the globe and in various subjects (Hsu et al. 2013; Wong et al. 2010). Davies et al. (2013) conducted a systematic literature review through the period of 2005–2011 on creative environments for learning in schools and found 210 educational studies supporting factors of creative skills development in children and young people. For example, Kwon et al. (2013) developed a web-based coordination tool based on metacognitive scaffolding principles to support classroom collaborative learning. Students can visualize their evaluations of their team process, thus facilitating positive interdependence.

The recent popularity of mobile and wireless communication technologies has attracted attention from many scholars who have developed mobile learning systems to verify the learning effectiveness of the intervention of such new learning models (e.g., Hwang et al. 2012; Shih et al. 2011; Wu et al. 2012). For example, Chen and Huang (2012) employed mobile and wireless communication technologies in a museum to integrate learning resources from both the real world and the digital world to help Taiwanese aboriginal students learn about their own culture. Moreover, contrary to the traditional deductive and inductive forms of inquiry investigations of science learning, Ahmed and Parsons (2013) proposed the abductive science inquiry approach with the mobile learning application "ThinknLearn" to assist students in generating hypotheses and to exploit their critical thinking abilities. In another study, Atif (2013) implemented a technology-enhanced studio-classroom to visualize conversations in class so that multiparty conversations in group activities could be more effectively facilitated. Cook et al. (2011) regard mobile phones as new cultural resources; among several of the arguments they advance, they present the notion of user-generated contexts as a means of integrating meaning-making from the world outside of schools into the school and its curriculum. Furthermore, Huang et al. (2012) applied procedural scaffoldings in a paper-plus-smartphone collaborative learning context. With precise and appropriate instructional strategies, technology can effectively facilitate learning collaborations.

Tatar et al. (2003) pointed out that mobile device-mediated learning can assist students in working at their own pace while conducting exploration activities and exchanging information with peers. Other advantages of applying mobile technology to learning include portability, instantaneity, adaptivity, facilitation of information acquisition, and enhancement of interpersonal interactions (Huang et al. 2008). As it creates more chances for instant and personalized social interactions, it promotes students' learning motivations. Meanwhile, students can explore and observe in a real environment and reflect on the content they have learned in the classroom.

Sharples (2013a) indicated that recent research has investigated the concept of "seamless learning," bridging gaps between learning tasks, contexts, and projects. Although many factors were concluded to influence the success of mobile learning, he pointed out that designing new forms of informal learning supported by personal mobile devices and evaluating learning that occurs outdoors and across locations are issues requiring investigation. Cook (2010) also stated that learning in and across contexts of use is complex. It requires researchers to consistently and systematically consider issues of the design and enactment of the mobile intervention.

Since mobile learning has become one of the learning model trends, many scholars have conducted related research using various mobile learning models. Mobile learning provides special functions for educational purposes. For example, Lai and Wu (2006) designed a mobile learning activity to allow students to share information and conduct group discussions with peers while taking part in the learning activities. Shih et al. (2010) not only integrated mobile devices with context awareness technologies to detect the situation of the learners but also applied a knowledge acquisition method to assist students in building comparative concepts of learning objects, such as distinguishing plant leaves. Meanwhile, the system was built with learning portfolio functions to document students' learning processes. It successfully provided seamless adaptive support during the learning process, which reflects the suggestion of Vavoula and Sharples (2002) and Wong and Looi (2011) that mobile learning should be an activity that is mediated in daily life and which can offer students a seamless learning experience.

Cook (2010) further described three phases of mobile learning: the first phase has a focus on using mobile devices for formal education, the second phase takes in field trips, and the third phase extends the learning scope to informal learning and lifelong learning. The affordances of the three phases incorporate mixed reality learning, context-sensitive learning, and ambient learning with augmented reality. He then proposed augmented contexts for development to solve a mobile-oriented educational problem and used design research as the approach to revisit the learning process, thus broadening the theory of blended learning. Sharples (2013b), on the other hand, introduced a computer system assisted with the Activity Guide software in his case for science learning. This system can orchestrate interaction between the teacher, the students, and the technology to conduct a productive learning activity that takes place both inside and outside the classroom.

In this chapter, the experiences of using mobile and wireless communication technologies to bridge classroom and in-field (i.e., learning space excluding the classroom) learning for a local culture course are reported. The instructional design reflects the ten features proposed by Wong and Looi (2011) of mobile-assisted seamless learning (MSL) to guide students to learn in both formal and informal learning situations. Such an educational setting extends the classroom learning time and space to the outdoors. The blended pedagogical design has also made the ubiquitous learning activities a seamless learning experience that encourages students to explore, investigate, record, analyze, synthesize their inquiries individually and collaboratively, and communicate as well as share their findings through both physical and digital means. Moreover, some preliminary findings from such blended mobile learning experiences are presented; that is, the students who learned with the proposed approach revealed significant improvements in terms of their learning attitudes, self-efficacy, and personal identification with the local culture.

Blended Mobile Learning Model

In recent years, various mobile devices such as smartphones and tablet PCs have developed exponentially. With the pervasiveness of the Internet and the availability of diverse application services, digital learning has evolved from computer-assisted learning to web-based learning and to mobile and ubiquitous learning (m-learning and u-learning) (Hwang and Tsai 2011). The trend of mediation between technology and instruction has fundamentally changed the traditional learning model in the way of providing more multimedia learning resources, offering personal assistance, creating extra interpersonal interactions, and extending learning activities beyond the classroom. Mobile learning encompasses more convenience and freedom to free learning from the confinements of time and space. Students are treated as more active and interactive learners (Huang et al. 2008). Mobile learning enables students to become immersed in different learning environments and contexts to continue their learning experiences, which not only augment their current learning achievements but also create potential learning prospects (Chan et al. 2006).

Definitions of mobile learning have transformed over time. Sharples (2000) defined that the purpose of mobile learning is to utilize the advantages of mobile technology to assist learning and increase learning achievements. Facer et al. (2004) argued that the aim of mobile learning is to use the portability and multiple functionalities of mobile devices to convert teacher-centered instruction into student-centered participatory learning, which encourages students to participate more actively in learning. Syvanen et al. (2005) added that mobile devices can help students to process information and make decisions in the learning environment. They provide students with in-depth course content and exploratory activities. More recently, Yau and Joy (2009) stated that using mobile devices in the learning process allows students to self-regulate by supporting their learning arrangements and regulating personal learning progress toward their goals. Compared to the traditional class-

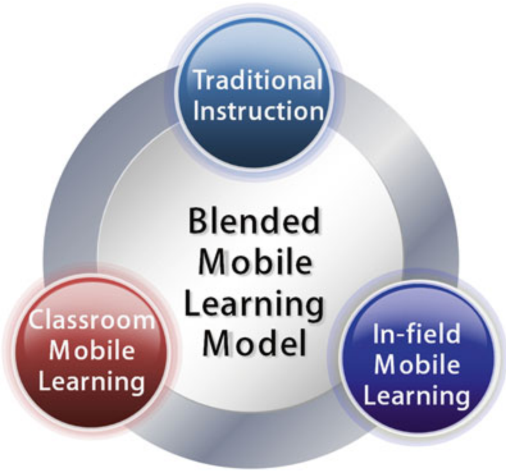

Fig. 16.1 The blended mobile learning model

room instruction model, students construct knowledge through tasks by exploring the problems instead of passively sitting in the classroom jotting down notes during lectures. Hwang et al. (2008) pointed out the importance of supporting students to learn in real-world environments using mobile, sensing, and wireless communication technologies; they further presented several instructional and assessment models for linking in-field observations to the knowledge learned in the classroom.

In Taiwan, a number of studies have been conducted to investigate the impacts of mobile learning models on students' learning perceptions (e.g., Hwang and Chang 2011; Shih et al. 2010). The results have revealed the potential of the use of mobile and wireless communication technologies in supporting classroom or in-field learning activities for local cultural courses. The students showed great interest in the learning and were highly supportive of the continuation of such learning activities. As a sequential and consequential follow-on from the previous studies, the goal of this research is to work toward the perfection of a seamless learning model and to sustain learning into extended time, which means bringing learning into a positive cycle developing from formal education into lifelong learning. Therefore, a blended mobile learning model is used to bridge the classroom and in-field instructions for an elementary school local culture course. As shown in Fig. 16.1, the learning model consists of three instructional modes, that is, traditional instruction, classroom mobile learning, and in-field mobile learning.

Wong and Looi (2011, p. 2367) identified ten salient features that characterize the MSL design, that is, encompassing formal and informal learning (MSL1); encompassing personalized and social learning (MSL2); across time (MSL3); across locations (MSL4); ubiquitous knowledge access via a combination of context-aware learning, augmented reality learning, and ubiquitous Internet access (MSL5); encompassing physical and digital worlds (MSL6); combined use of multiple device types (MSL7); seamless switching between multiple learning tasks (MSL8);

knowledge synthesis via a combination of prior and new knowledge, multiple levels of thinking skills, and multidisciplinary learning (MSL9); and encompassing multiple pedagogical or learning activity models (MSL10).

The blended mobile learning model proposed in this research reflects the ten features in its instructional design. Each student is equipped with a mobile device. In the learning environment, wireless communications are provided, so that the students can access the digital content (MSL5) as well as interact with the learning system at anytime (MSL3) and from anywhere (MSL4). Moreover, the two mobile learning modes help the students connect the content of their textbooks or what they have learned in the traditional instruction to the digital resources and real-world learning targets (MSL6).

The classroom mobile learning mode aims to link the standard textbook knowledge to digital resources via asking extensive questions based on the textbook content of the classroom activities. Students are asked to seek answers to a series of questions related to a topic, which is an extensive issue based on the textbook content taught with traditional instruction. The answers can be acquired by accessing supplementary material databases suggested by the teacher or by using a search engine to search for relevant information on the Internet via mobile devices. Students can further organize the collected information and share their findings on a discussion system via their mobile devices (MSL7, MSL8). In addition, students are encouraged to discuss their findings and conclusions with peers in a face-to-face mode (MSL2). They can present and compare individuals' findings during the learning process by looking at each other's devices. Such a classroom mobile learning activity not only fosters students' notions of solving problems and finding extensive information of textbook content via accessing the digital sources but also engages them in meaningful peer interactions (MSL1, MSL9).

On the other hand, the in-field mobile learning mode intends to scaffold students to construct knowledge by invoking a two-stage questioning approach in the field, such as in ecology parks, butterfly gardens, and museums. Such an in-field mobile learning mode not only guides the students to observe, identify, and compare features of real-world learning targets but also helps them connect the real-world information to the knowledge learned from the textbooks by asking them relevant questions and providing them with supplementary materials via mobile devices and wireless communication facilities (MSL1, MSL10).

Before leading in mobile technologies in schools, the following preparation work needs to be carried out:

1. Digitalizing the learning content, including learning materials, learning sheets, and test sheets. It is suggested that the learning materials be provided by the content providers. Schoolteachers should pay attention to the development of learning sheets and the design of learning activities.
2. Setting up the learning environment, including the wireless network and server. If the schools are unable to provide Internet access to the students, some web-based information searching tasks can be replaced with information seeking tasks in the real world, such as finding relevant books in libraries, interviewing people, collecting data via questionnaires, or making observations in particular areas.

Table 16.1 Categories of course units from the aspects of mobile learning design

Category	Features or criteria
Traditional instruction	It is necessary to engage students in drawing or writing with paper and pencils
	It is necessary to transfer knowledge of the course units to students via the teacher's instruction
	The students need to produce a real artifact
Classroom mobile learning	Supplementary materials or extended learning is needed to help the students have a global aspect, think in depth, or learn more about the course unit
	Some issues in the course units are worth further investigating via seeking information on the web
	If the content of the course units is abstract, presenting the content with simulation software could help students comprehend it
	If the content of the course units is boring, presenting the content with multimedia could promote students' learning interest
	To master the learning content, operational practices are needed
In-field mobile learning	Situating students in some real-world learning scenarios could help them comprehend the learning content of the course units
	Situating students in some real-world learning scenarios could help them connect the knowledge learned from the textbooks to their daily lives
	It is necessary to have students experience the real-world learning targets with digital supplementary materials
	It is important to engage students in investigating real-world environments with learning guidance, supplementary materials, or hints from the learning system
	Students need to seek supplementary materials from the Web when learning in the real world or observing the real-world targets.
	Students need to learn to identify or classify real-world targets with supports from the learning system or the Web

3. Examining and categorizing the course units. It is important for teachers to examine the course units they teach and classify the units into three instructional categories, that is, traditional instruction, classroom mobile learning, and in-field mobile learning. This can be done by following the criteria listed in Table 16.1.

Example of Developing a Seamless Learning Environment for a Local Culture Course

Figure 16.2 shows an example of a seamless mobile learning system implemented based on the blended learning model. It consists of the knowledge-finding mechanism, the learning guidance mechanism, the test item database, the learning material database, the learning portfolio database, the student profile database,

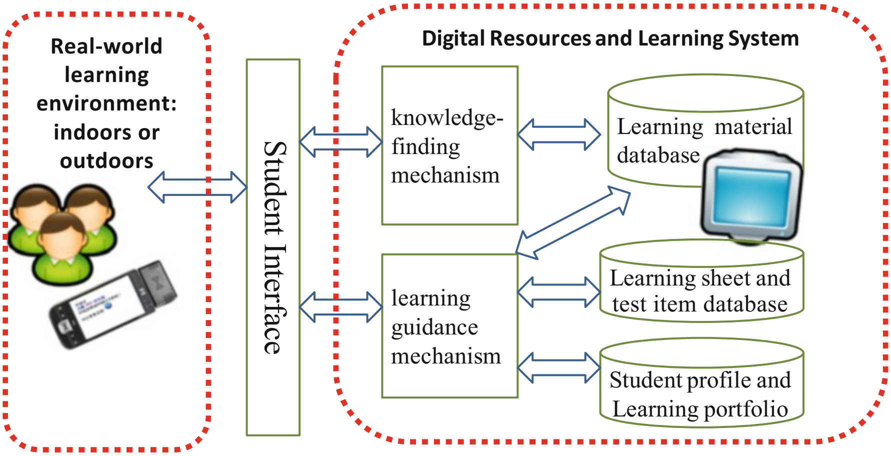

Fig. 16.2 The structure of the blended mobile learning system

Fig. 16.3 Classroom mobile learning scenarios

and the teacher interface. The learning mechanisms and user interfaces were developed with the Java programming language.

The knowledge-finding mechanism enables students to access digital materials (e.g., learning task descriptions, hints for the learning tasks, or supplementary materials) via scanning the QR codes on physical learning targets (e.g., printed learning sheets or test sheets or learning targets in the field). For example, in some classroom activities, there are QR codes on the printed learning sheets. The students can access the corresponding supplementary materials on the Internet by scanning the QR code that represents each question or learning task. In the in-field activities, QR codes are attached to the real-world learning targets. Once the students scan the QR codes, the learning system senses their locations. Accordingly, it can provide relevant materials or learning guidance at the right time in the right place.

Figure 16.3 shows an illustrative example of student-system interactions using QR codes in the classroom. The students need to complete a learning sheet by answering a series of questions related to a target issue. For each question presented

Fig. 16.4 In-field mobile learning scenarios

on the learning sheet, there is a corresponding QR code. The students are able to access some relevant supplementary materials via scanning the QR code with their mobile devices; alternatively, they can invoke search engines to search for information on the Internet.

Figure 16.4 shows an example of learning in the field. In this example, the real-world learning environment is a temple, in which several learning targets are labeled with QR codes by the teacher in advance. During the learning process, the learning tasks are presented in the form of prompt questions to guide the students to explore and make observations in the field. The learning guidance mechanism employs a two-stage questioning approach to help the students make in-depth observations and complete their learning tasks in the field.

Figure 16.5 shows the flowchart of the two-stage questioning approach. After logging into the learning system, the students are guided to find a set of learning targets. When they arrive at the location of a learning target, the learning system asks them to confirm their location by using the mobile devices to scan the QR code on the target. After confirming the location of the group, the learning system presents the learning tasks and supplementary materials to the students. Following that, a series of questions is presented to the students to guide them to observe and identify the key features of the learning targets. If the students correctly answer the questions, an assistance procedure is invoked to guide them to identify the next learning target. If they fail to correctly answer the questions the first time, the system will give hints to guide them to make further observations and read the supplementary materials. If the students fail to answer correctly again, the system will then present the correct answers to them.

Practical Application and Findings

An 18-week learning activity was conducted for an elementary school local culture course in southern Taiwan based on the blended mobile learning model. The in-field learning environment was Chao-Xing temple. Visiting the temple has been part of the curriculum of the target school for many years. The course aims to introduce the

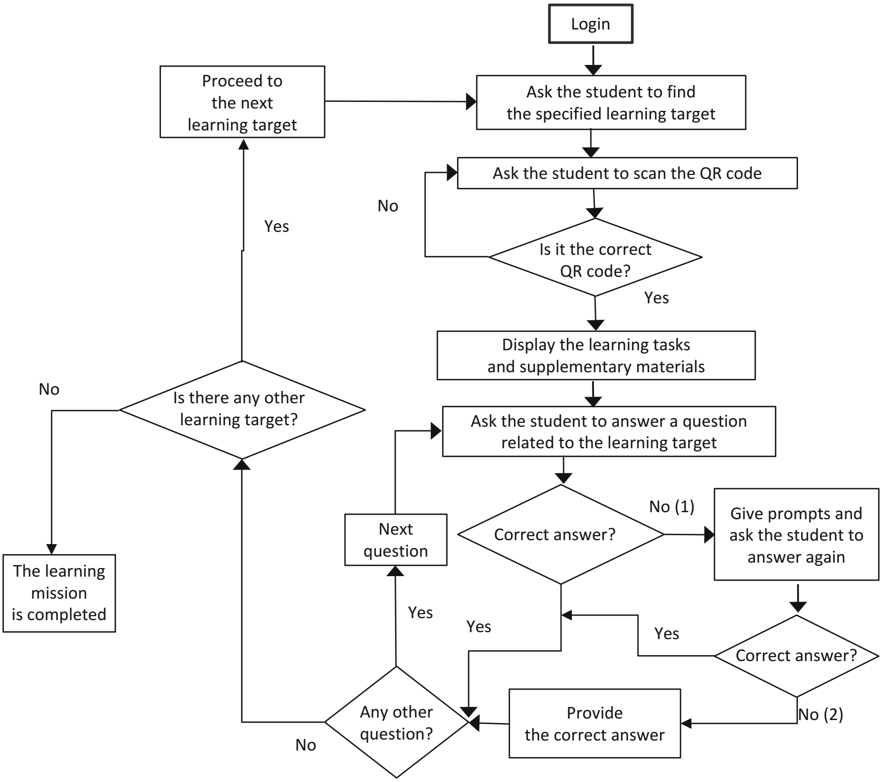

Fig. 16.5 Flowchart of the two-stage questioning approach

ancient language, customs, history, carving art, painted murals, and the gods of Taiwan. Each dimension includes several learning targets, such as the stone-carved lions in the main hall and the long-pan pillars in the front hall of the temple. A total of 26 fifth graders participated in this study.

Before and after the learning activity, all of the students were asked to fill in the questionnaires for measuring their identification with the local culture and their interest and self-efficacy in learning the course based on the measuring tools developed by Hwang and Chang (2011) and Wang and Hwang (2012). From the collected data, it was found that the students' local cultural identification was significantly improved after participating in the blended mobile learning activity. According to their answers to the questions, the students showed a strong will to preserve the artifacts, living environment, and traditional cultural customs and activities and were willing to show them to friends. Moreover, the students' interest and self-efficacy of learning the local cultural course were significantly increased as well.

To further investigate the effectiveness of the blended mobile learning approach, an interview was conducted after the learning activity in which several questions related to the learning approach were asked, such as "What are the advantages and disadvantages of such a learning activity?" and "What are the major differences between this learning activity and other learning activities in which you have participated?" It was found that the students shared a consistent point of view; that is, they considered the benefits of the blended mobile learning approach as "providing systematic guidance" and "linking the observations to prior knowledge."

In terms of the provision of systematic guidance, most of the students highlighted the value of the learning guidance mechanism. They believed that this mechanism was helpful to them in completing the learning tasks owing to the provision of the two-stage prompts. For example, one of the students indicated that "Unlike the one-to-many instruction given by the teacher, the mobile learning system provides step-by-step prompts or hints based on what I need, which is helpful to me in completing the learning tasks." They like to work with peers, share knowledge with peers, and receive others' feedback on their answers. They are also fond of using mobile phones to learn with the system because the technological guidance is like a personal tutor leading them to in-depth learning.

As for the perspective of linking the observations to prior knowledge, several students shared the same position; that is, via the knowledge-finding mechanism, they were able to link what they observed in the field to what they had learned from the textbooks. Six students shared the same opinion that they were engaged in recalling what they had learned in the class and what they had observed in the field in order to propose questions. Five students indicated that such a mobile learning approach helped them reflect on what they had learned, no matter whether from the textbook, in-class instruction, or the field observations. One of the students further stated that "It is encouraging to find that the knowledge learned from the textbooks is relevant to, or even helpful for, what we are observing in the temple." They showed a stronger sense of achievement, as well as higher individual and even group self-efficacy to reach the learning goals.

Discussion and Conclusions

Brown et al. (1989) perceived the importance and necessity of real-life learning activities and emphasized placing students in contextual learning situations in order to train their real-world problem-solving skills. Among all the content areas in which mobile learning is used, social science courses are particularly problematic in terms of their system design and model establishment. This is due to the genuine differences in the nature of the subjects in that science, the natural sciences, and even language learning tend to have a specific concept structure with fixed answers to questions, whereas social science has a more fluid conceptual structure. Social science encompasses more human/science implicit content and flexible answers. Consequently, the instructional design of social science subjects tends to be more explorative than investigative and more affective oriented than cognitive oriented. Although social science is different in nature from other subjects, many studies have endeavored to use the functions of mobile technologies to magnify the learning of culture and history.

A major leap from the concept of mobile learning to seamless learning is to not only use mobile devices to bring students' learning from the classroom into the field but also to bridge the gaps between the learner and time, space, peers, resources, and living environment. Learning is no longer confined by explicit and tacit limitations; it is continuous, unlimited, and empowered. Technology is used to sustain students' academic and lifelong learning and to foster their abilities to experience life and learn from life.

Future Research Issues

From the application presented in this chapter, it is concluded that students can be benefited by the blended mobile learning model that provides seamless learning supports for helping them link the knowledge learned from the textbook and the information derived from the Internet to real-world experiences. Therefore, it would be worth investigating several relevant research issues by taking more computer technologies, educational technologies, or learning strategies into consideration to provide more effective seamless learning environments in the future. Some potential research issues are suggested as follows:

1. Conducting well-designed experiments which compare the learning outcomes of the blended mobile learning approach with those of traditional instruction or other mobile learning approaches. To make valuable and convincing conclusions, it is necessary to design experiments with at least one control group to make sure that the improvements in students' learning outcomes can be attributed to the proposed approach.
2. Extending the blended learning model by leading in other strategies. For example, several studies have reported the potential of mobile games for improving the learning motivation of students. For example, Huizenga et al. (2009) researched the use of mobile games in secondary education and their effects on students' knowledge of medieval Amsterdam and their motivation to learn history. By the storyfication of the learning activity, students met people from medieval times in a real environment with mobile phones acting as guides and communication tools. Therefore, it is expected that the lead-in of such learning strategies can promote students' learning motivation as well as their learning performance in blended mobile learning activities.
3. Integrating emerging computer technologies (e.g., augmented reality, cloud computing, and GPS positioning technologies) into blended mobile learning activities for local cultural courses or other social studies courses. For example, Ch'ng (2009) indicated that with the help of such emerging technologies, students can experience and solve environmental problems in a virtual archaeology learning environment (e.g., the nineteenth century) as they travel through time in

interactive 3D games. Moreover, there are researchers (e.g., Tussyadiah and Zach 2012; Newsome et al. 2012) who have used GIS and GPS guidance systems to guide users to explore the environment and to communicate with others by sharing and discussing geographical knowledge so that learning becomes more interactive and meaningful. It is expected that with the help of new technologies, problem-solving activities can be conducted both in classrooms and in the field and hence a seamless learning environment can be provided to help students link the knowledge learned from the textbooks to their daily experiences, combining what they have found on the Internet and what they have observed in the real world.

4. Integrating social community media into blended mobile learning activities for local cultural courses or other social studies courses. For example, Lewis et al. (2010) used Mobltz social community media to foster generative learning communities to enhance informal learning interactions. It is expected that via the use of social community media, students will have opportunities to present and share what they have observed and learned from the blended mobile learning tasks; moreover, they will be able to make reflections on their learning performance or tasks based on the information shared by their peers.
5. Providing learning tools such as concept mapping and annotation systems for use in blended mobile learning activities in local cultural courses or other social studies courses. Researchers have indicated the importance and necessity of providing effective learning tools in mobile and ubiquitous learning environments. For example, Schepman et al. (2012) reported the benefits of offering students a series of courses, such as natural science, social science, arts and humanities, and so forth, with a cloud computing-driven note-taking system to support students' thinking and organizing skills and making reflections. Such learning tools could also be helpful to students to more effectively learn while taking part in blended mobile learning activities for local culture courses.

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Chapter 17
What Makes the Design of Mobile Learning Trails Effective: A Retrospective Analysis

Hyo-Jeong So, Esther Tan, Yu Wei, and Xujuan Zhang

Abstract In this chapter, we trace the design and enactment of two mobile learning trails, which were designed to provide seamless learning experiences where students could apply and build knowledge across varying contexts, content, and situations. Employing design-based research as a methodological tool, we conducted a retrospective analysis to unpack critical design elements that could possibly determine the effectiveness of a mobile learning trail, which was defined as a series of learning activities in and out of school mediated by mobile devices and applications. The retrospective analysis revealed three design elements that appeared to influence and shape the impact of mobile learning activities on the learning process and outcomes. First, putting in place a pre- and post-trail phase is imperative to establish a learning continuum linking classroom and outdoor learning contexts. A central task in design process is to support a seamless flow of learning across contexts, which requires a tight coupling of understanding main learning content, determining meaningful learning contexts, and facilitating continuity in the whole learning process. Second, the design of mobile learning ought to see an effective combination of both designed and user-generated activities, which encapsulates both macro-level external goals and micro-level situational goals pertaining to the specific outdoor setting. The former serves as a preconditioning measure to reduce novelty space, and the latter affords an unstructured learning space where students can leverage on the rich physical affordances to pursue their own inquiries. Third, it is imperative to provide "common grounds" to foster and to sustain collaborative knowledge

H.-J. So (✉)
Department of Creative IT Engineering, Pohang University of Science and Technology, Pohang, South Korea
e-mail: hyojeongso@postech.ac.kr

E. Tan
Munich Center of the Learning Sciences (MCLS), Ludwig-Maximilians University, Munich, Germany

Y. Wei
Learning Sciences and Technologies, National Institute of Education, Nanyang Technological University, Singapore, Singapore

X. Zhang
Learning Sciences Laboratory, National Institute of Education, Nanyang Technological University, Singapore, Singapore

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creation and advancement across varying contexts and time scales. This serves to enhance continuity of collaborative discourse from the classroom to the outdoor and back to the classroom. We believe that our retrospective analysis presented in this chapter can serve to widen and deepen our knowledge base on the critical factors and elements for designing effective mobile learning activities arising from situated learning perspective.

Introduction

The rapid advancement and emergence of technological devices and tools sees an increasing volume of research and literature in the field of mobile learning. Research efforts in designing software applications and in integrating technology into teaching and learning are moving toward equipping and empowering the learner across seamless learning contexts (e.g., Hwang et al. 2011; Liu et al. 2009; Maulucci and Brotman 2010; Rogers and Price 2008; Vavoula et al. 2009). However, there remain little research and validated models on designing seamless learning contexts linking teaching and learning in and out of the classroom. Integrating and harnessing technological affordances per se would not suffice to bring about the desired outcomes of seamless learning. It is thus pivotal to align both the technological integration and the pedagogical intent with the design of seamless learning situations.

The goal of our 3-year design-based research on mobile learning presented in this chapter is to design mobile learning activities, giving focus to the learning process and conditions whereby learners are engaged in creating meaningful contexts and content through the mediation of mobile technologies and collaborative meaning-making practices. With the rapid adoption and diffusion of mobile devices, many schools have been exploring ways of integrating mobile technologies into curricula. To a large extent, the design of mobile learning activities in schools is still very much tied to academic goals and achievements. When the unique affordances of mobile technologies and applications are not fully utilized, mobile learning activities designed may reinforce the traditional notion of teaching and learning, which focuses on individual cognition and measurable academic performance.

Our research undertaking in mobile learning involves *designing for change* (Barab et al. 2004, p. 265), where we emphasize the potential of mobile learning to challenge and to change the current practices of teaching and learning in schools. Toward this goal, our research agenda gives emphasis to two critical and related elements in the design approach, namely, knowledge creation space and seamless learning. First, we aimed to design a *knowledge creation space* where learners are actively engaged in building knowledge, leveraging on the rich interaction with the physical environment and the authentic resources via a collaborative discourse (So et al. 2012). In such a knowledge creation space, mobile technologies and applications play a critical mediation role to extend and integrate learning experiences across multiple contexts, content, and time scales.

Next, we position what we call a *mobile learning trail* as an essential mechanism in design that anchors seamless learning experiences in a knowledge creation space.

We define a mobile learning trail as a series of learning activities in and out of school mediated by mobile devices and applications. While a mobile learning trail resembles the underlying idea of a field trip (Orion and Hofstein 1994) or place-based education (Grünewald 2003) that create been adopted in school contexts, the conception of mobile learning trail foregrounds our theoretical stances toward the changing nature of knowing and learning. By *mobile*, we emphasize our belief on the unique affordances of mobile technologies and applications that enhance connectivity and mobility in learning process. By *learning*, we adopt a broad definition of learning that goes beyond the traditional dichotomy between formal learning and informal learning and aim to support pervasive knowledge building practices across contexts. By *trail*, we highlight the criticality of learners' navigational learning experiences in multiple spatial and temporal spaces (Peterson and Levene 2003).

In this chapter, we trace the design and enactment of two mobile learning trails, which were designed to provide seamless learning experiences where students could apply and build knowledge across varying contexts, content, and situations. Employing design-based research as a methodological tool, we conducted a retrospective analysis to unpack critical design elements that could possibly determine the effectiveness of a mobile learning trail. Design-based research involves multiple cycles of design, enactment, evaluation, and redesign, with an aim to refine and to advance both theory and practice (Barab and Squire 2004). Design-based research is particularly useful to examine the complexity of designed contexts or systems that includes multiple interacting elements of different types and levels (Cobb et al. 2003). We view mobile learning as a complex learning ecology owing to the unpredictability of the context, the mode of use, and the learning process (Sharples et al. 2009). Cobb et al. (2003) argue that a systematic retrospective analysis is a critical methodological step in design-based research to unpack "the intimate relationship between the development of theory and the improvement of instructional design for bringing about new forms of learning" (p. 13). Consistent with this view, we believe that our retrospective analysis of the mobile learning trails can provide invaluable insights on the design of new forms of mobile learning activities, as well as enhancing our knowledge base on the design theory of mobile learning.

Context for the Current Study

Research Context

This design-based research was conducted in a local secondary school, one of the future schools in Singapore. The future school initiative by the Singapore Ministry of Education aims to select exemplar schools that demonstrate a high level of technology integration across all subjects and levels. As such, the research school also emphasizes seamless and pervasive use of technologies in the teaching and learning process. With the implementation of 1:1 computing, each student in this school owns a notebook computer (i.e., MacBook), and other types of mobile devices such as iPads are also available for lessons.

With such a strong IT infrastructure in place, we explored the integration of the mobile technologies and applications into the core curricula, particularly the design of mobile learning trails in the teaching of integrated humanities (i.e., history and geography). Over 3 years, we have designed and implemented four mobile learning trails at various locations in Singapore. In this chapter, to identify factors that make the design of mobile learning trails effective, we particularly focus on the design and enactment of two mobile learning trails. The retrospective analysis of these two trail designs showed that the participating teachers and students had different perspectives on the learning effectiveness and process of the trail design.

Overall Design Structure

Our primary pedagogical intent is to design the situation for *intentional learning experiences* across space and time where students continuously pursue own inquiries and collectively create knowledge. To this end, we first identified a BIG (Beyond Information Given) question that served as an overarching inquiry goal that students would pursue through various activities. BIG questions are usually ill-structured, complex problems, which require deep understanding about core ideas and concepts in a given topic. Under a BIG question, we adopted a *three-stage learning model*, which refers to the integrated design of pre-trail, trail, and post-trail activities (So and Tan 2014):

- *Pre-trail activities* prepare students cognitively and psychologically for the outdoor mobile learning trail with specific activities to activate students' prior knowledge on trail sites and events, as well as cover core conceptual knowledge and skills related to subject areas and BIG question. These activities also serve to scaffold and to guide students to generate individual and group inquiries.
- *Trail activities* involve outdoor learning activities where students interact with the environment, resources, and information available in a physical location to build knowledge in situ.
- *Post-trail activities* assist students to consolidate their field trip experiences and rise above their ideas toward more comprehensive understanding. This rise-above activity (one of the core principles of knowledge building; Scardamalia 2002) is mediated by online learning platforms such as Knowledge Forum that promote collaborative knowledge building practices.

Designing Two Mobile Learning Trails

The three-stage model guided the overall structure of design from pre- to post-mobile learning trail activities. The detailed descriptions of learning activities at each stage of the mobile learning trails are presented in Table 17.1.

Table 17.1 Descriptions of mobile learning activities at each stage

	British Defense Strategy Trail	River Mystery Trail
Pre-trail	Introduce the BIG question and undertake tune-in activities on Fort Siloso and British defense plan.	List three famous rivers in the world and their common features and functionalities.
	Generate hypothesis and develop own line of pre-trail inquiries, i.e., what student groups want to find out during the trail.	Develop one group pre-trail inquiry/ hypothesis relating to the BIG question on river and civilization.
Trail[a]	Calculate the distance from the cliff to Pulau Palawan.	Measure river water conditions.
	Identify whether the vessel is "friendly" or "hostile" using the chart at the watchtower.	Determine the location for ideal water conditions and explain the reason why the location has ideal water conditions.
	Give reasons for erecting another tower in this area and describe the role and purpose of the tower and the guns.	Pursue own line of inquiry (in small groups) in the unstructured learning space (students are free to move around in the vicinity of the river site to investigate the pre-trail inquiry and hypothesis).
Post-trail	Share learning experiences at the trail: learning points and reflections.	Share collated findings and emerging new concepts in response to the BIG question
	Revisit answers and data collected to some of the more pertinent questions, which require critical thinking/problem solving skills.	Attempt a rise above by reviewing the responses to the BIG question in Knowledge Forum and identifying new knowledge and concepts to advance their ideas at the class level.

[a]*Note:* Only selected activities are described due to space limit

British Defense Strategy Trail This mobile learning trail was designed and implemented at the Fort Siloso fortress, located at the western tip of Singapore. The overarching BIG question "What is the role of Sentosa in the British's big plan of defense?" guided the development and the design of a series of activities at each of the four learning stations during the trail. The collective undertaking of the activities aimed to lead the students to answer the BIG question. During the pre-trail stage, the students were introduced to the BIG question, and scaffolds in the form of tune-in activities on trail sites and events that serve to guide students to generate their own pre-trail inquiries they would want to pursue during the learning trail. On the day of the outdoor trail, participants in teams of 3–4 students shared one iPad, visited the four learning stations at the Fort Siloso (see Fig. 17.1), and undertook tasks that ranged from well-structured problems like simple application (e.g., calculating the distance between two physical locations) to ill-structured problems (e.g., describing the role and purpose of certain objects in relation to their historic and strategic importance). Back in the classroom, the teacher led a post-trail lesson to encourage the students to share their learning experiences and to review and consolidate the key findings of some of the trail activities pertinent to the BIG question.

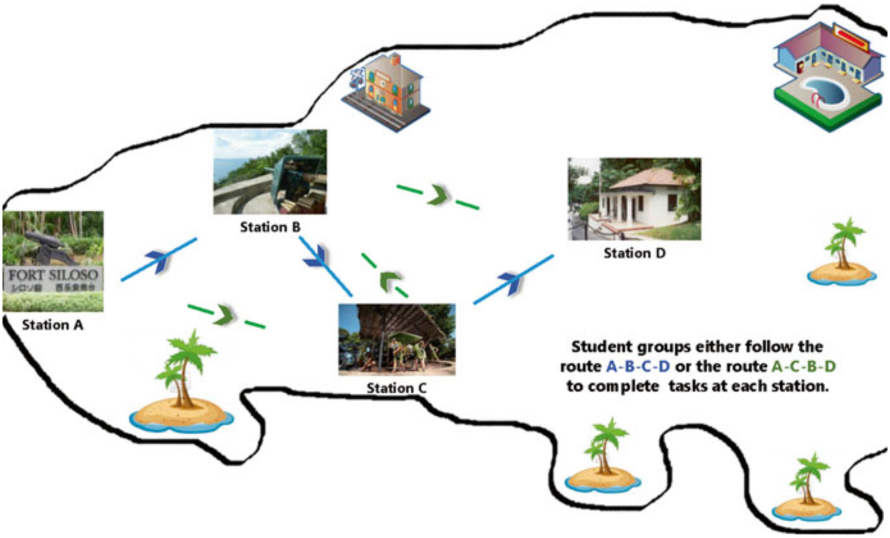

Fig. 17.1 Activity sequence and structure in British Defense Strategy Trail

River Mystery Trail This trail was designed and implemented at the Singapore River in August 2012. The BIG question for this trail was, "Why does civilization start at river mouth?" Similar to the previous trail, the River Mystery Trail included a series of activities from pre-trail to post-trail stages. While the overall structure was similar to the previous trail, we added new structures and components in the design of the River Mystery Trail as a *repairing mechanism* (Collins et al. 2004) to improve our design. Three major modifications were made as follows:

- *Split-and-merge collaboration*: Lack of time to explore learning stations was a consistent issue in the execution of mobile learning trails. Overall observation of interaction and discourse patterns in the previous trail implementation showed that the students tended to focus on completing tasks in a competitive manner rather than to engage in deep meaning-making process, and this learning pattern was mainly driven by students' attitude to complete as many tasks as possible in a given time (Tan and So 2011). To promote active interaction and collaboration within and across groups and to foster deep engagement with the physical environment, we decided to reduce the number of learning stations and tasks that students needed to complete. By using a split-and-merge collaboration structure (see Fig. 17.2), the students in a group of four were split into two pairs and started their field investigation at two different points along the Singapore River. The two pairs of the same group then merged at the point of Clarke Quay where they could exchange their field investigation findings and data collected at the different activity stations.

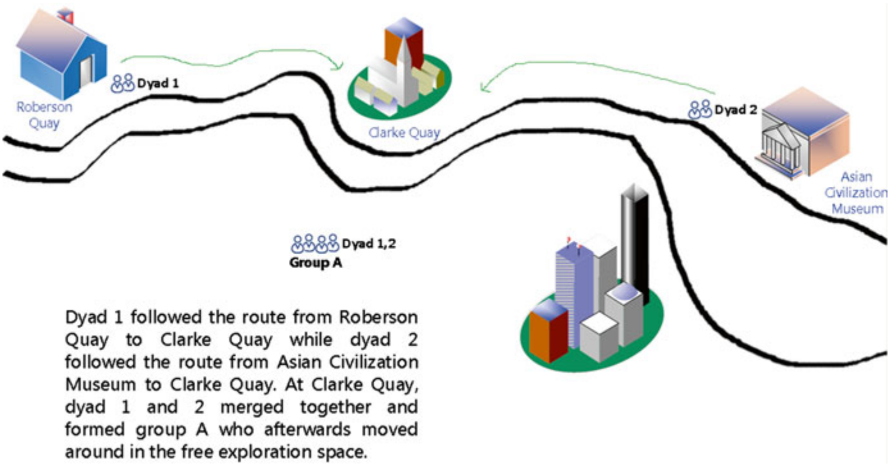

Fig. 17.2 Activity sequence and structure in River Mystery Trail

- *Unstructured learning space*: Related to the issue above, our findings from two previous interventions showed that students' competitive actions and superficial engagement were driven by the degree of control and ownership given to the students, where they were merely responding to the series of tasks designed a priori by the teachers and researchers. To restore more control and ownership to the students, we factored in an unstructured learning space during the outdoor trail where the students could freely investigate own inquiry questions co-generated with group members during the pre-trail stage. In this unstructured learning space, teacher facilitation is minimized while students assume more agency and responsibility for own learning processes and outcomes.
- *Knowledge Forum*: We observed that to foster pervasive intentional learning among the students, there was a critical need to have a central public space where the BIG question is visible to the students for the generation and improvement of ideas beyond small group settings. From pre-trail to post-trail stages, Knowledge Forum (Scardamalia 2002) served as a main technological platform where the students generated inquiries, put forth hypothesis, shared rich experiences gained from outdoor trail activities, and ideas collectively.

On the use of mobile devices in both trails, students in small groups used an iPad as a main mobile device to access the Web-based platform called SquareCrumbs (see Fig. 17.3) that hosted all learning activities. The Web-based platform also allowed the students to host all their findings, data, and notes and to interact with other group members and teachers through the synchronous broadcasting and feedback features. In the River Mystery Trail, the students were provided with data loggers and probes for measuring the water conditions, which was one of the main inquiry activities.

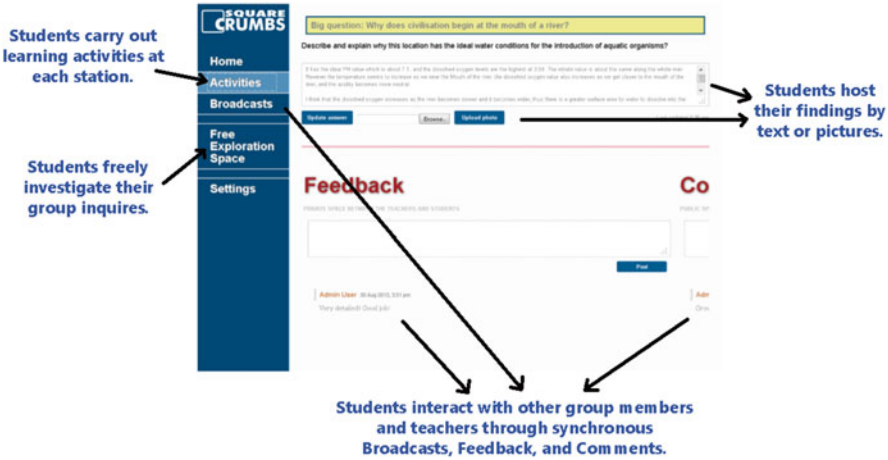

Fig. 17.3 Web-based platform on iPad

What Makes the Design of Mobile Learning Trails Effective

Adopting design-based research affords a continuous review and redesign process to advance both theory and practice. As aforementioned, we added new structures and components as repair strategies to improve the design of the mobile learning trails. Forty-three students from two classes participated in both mobile learning trails and associated learning activities. After the implementation of the River Mystery Trail, the students were put into small groups (5–7 students per group) for semi-structured interviews (45 min to 1 h) on the following themes: (a) trail design and trail tasks (pre- to post-trail), (b) critical thinking and collaborative knowledge building, (c) technological support and impact on collaborative knowledge building, and (d) facilitation. We also interviewed two teachers who participated in the design and the enactment of the mobile learning trails. Interviews conducted with the students and teachers who participated in both mobile learning trails, however, revealed seemingly different perceptions on the effect of and satisfaction with the two mobile learning trails. The students perceived the British Defense Strategy Trail to be much more engaging and enjoyable than the River Mystery Trail, while the teachers measured the effectiveness of the design from the perspective of the learning process and the desired learning outcomes. The different perceptions from the teachers and students motivated us to conduct a retrospective analysis to closely examine what makes the design of mobile learning trails effective. In the section below, we compare and contrast the two mobile learning trails to unpack what are critical features and elements for designing effective mobile learning trails.

Establishing an Optimal Level of Novelty Space

Orion and Hofstein (1994) advocated the need to see field trip(s) as an integral part of the entire curriculum rather than a stand-alone, 1-day event, and focus on the day of field trip should be given to interaction between learners and the physical affordances of that learning environment. They also surfaced the concept of *novelty space*, which consists of three interrelated aspects of a field trip study, namely, *the cognitive*, *the geographical*, and *the psychological*. Cognitive novelty refers to the concepts and skills that students are asked to perform during field trips, whereas geographical novelty means students' acquaintance with field trip areas. Psychological novelty means students' prior experiences in field trips as social adventurous events. Orion and Hofstein (1994) observed that students showed better learning performance on the field trip when this novelty space was reduced with pre-field trip preparatory lessons.

In our research context, pre-trail lessons functioned as a mechanism to reduce the level of novelty space and to increase students' readiness. That is, the level of cognitive novelty was reduced with the delivery of lessons that covered basic concepts and knowledge necessary to perform field trip activities. We could also assume that the students did possess an appropriate level of psychological readiness to perceive a mobile learning trail as a learning event since they had participated in similar outdoor learning experiences previously. How the students perceived the degree of geographical novelty, however, was different in the two mobile learning trails. While the students were familiar with both locations to some extent, they found the Fort Siloso area more attractive and enjoyable for learning than the Singapore River.

As to why and how the sense of location matters, we contend that such differences in student perceptions about physical locations are related to how an optimal level of novelty space, especially the geographical novelty, is established as part of preconditioning. By an optimal level, we caution that maximizing familiarity with physical locations during preconditioning could be equally dangerous if students' motivation and intention for learning are not sufficiently activated for situational learning. Particularly, when students are exploring physical locations where they have some level of prior acquaintance, the locations have to be contextualized to enable *situational (re)interpretations* (Kerawalla et al. 2012). Such contextualization can be done by presenting a specific learning scenario/story or engaging students to perform certain roles. For instance, in our study, prior to the British Defense Strategy Trail at Fort Siloso, a facilitator acting as a British soldier gave the students the following scenario:

> Attention! Listen up. As you know, you are soldiers sent back in time to the year 1930, pre-war Singapore. Your mission is to gather vital information for the defense of Fort Siloso. You will use this information to reverse the defeat of the British. Your first task would be to determine the bearings of that gun right there. Use your standard army issued iPad and the compass in your iPad, to determine the exact bearing of the gun there.

This scenario given to the students added a different layer to the familiar physical location. In this recontextualized place, the students had to make situational (re)interpretations of known facts and familiar objects and resources at Fort Siloso by taking the perspectives of British soldiers and sometimes geographers or historians. Such contextualization of the field trip location, however, was absent in the River Mystery Trail. The pre-trail briefing delivered mainly focused on direct instructions and procedural information and failed to add a new layer to the physical location where the students were rather familiar with.

Designing Tasks for Control and Context

Kukulska-Hulme et al. (2007) suggest that mobile learning activities are generally categorized into *designed activity* and *user-generated activity*, depending on who the main agent is, in the design of the learning content and context. Designed activity is carefully crafted a priori by teachers and/or researchers, while user-generated activity arises from learner's own spontaneous requirements.

In our research context, we experimented with both activity structures. The British Defense Strategy Trail mainly included designed activities in predetermined locations, whereas the River Mystery Trail included both designed activities and user-generated activities. That is, in the River Mystery Trail, we gave the students more control in their learning process by engaging them in an unstructured free exploration place, which is one typical kind of user-generated activities where students are free to propose their own inquiry and to perform necessary actions within a physical environment in the process of pursuing their inquiry (Maulucci and Brotman 2010).

Despite our design intention to give more agency and control over to the students, they appeared to be more engaged in interacting with the physical environment in the British Defense Strategy Trail than in the River Mystery Trail. From learning design perspectives, we decided to closely examine the nature of activity types in each trail and found that the level of student engagement and interaction is likely to be influenced by (a) the way how control is distributed across multiple agents including peers, teachers, and technological tools and (b) the extent to which specific tasks incorporate contextual variables and resources available in a physical location.

First, we contend that giving more agency and control over to students is not a sufficient condition for effective mobile learning unless teachers and technological platforms provide additional support and facilitation. Teachers' involvement in student learning outside the classroom can vary in forms. Maulucci and Brotman (2010) suggest that teacher involvement can include strategies in forms of both structured and unstructured engagement. Structured engagement strategies tend to emphasize seeking or receiving information from students, while unstructured engagement focuses on following students' interests, inspiring their thinking, and facilitating free exploration.

On the whole, we found that in the British Defense Strategy Trail, the teachers employed both structured and unstructured engagement through on-site and online facilitation. For on-site facilitation, the teachers were located in different places to guide students' navigation across four learning stations. For online facilitation, technological platforms played a critical mediating role to provide appropriate facilitation for helping students build knowledge in situ. Intergroup communication and communication with the teachers, who were distributed in different locations, were possible through the public place "Comments" and "Broadcast" in the Web-based platform (refer to Fig. 17.3). In the River Mystery Trail, however, teacher facilitations tended to rely more on structured engagement, which was mainly about receiving and sending information from/to students. That is, the nature of teacher facilitation focused on direct instructions and procedural announcement.

Second, another critical factor lies in how the design of specific tasks incorporates contextual variables and resources available in a given physical location. Here, context means more than a physical location. Context is "the problem's physical and conceptual structure as well as the purpose of the activity and the social milieu in which it is embedded" (Rogoff 1984, p. 2 as cited in Choi and Hannafin 1995, p. 54). Designing mobile learning activities should take into account the nature of context to facilitate learners' meaningful and active engagement with physical surroundings, resources, and tools (Kukulska-Hulme et al. 2007; Pachler 2009; Sharples et al. 2007). That is, physical objects and artifacts around field trip locations should be incorporated into the core elements of designing tasks.

Generally, the existing literature views and categorizes learning tasks in terms of the degree of s*tructuredness*, which can range from well-structured to ill-structured tasks (Kapur and Kinzer 2007; Strijbos et al. 2004). Well-structured tasks are chiefly fact-based tasks with one definite answer, while ill-structured tasks require analyzing and synthesizing gained resources toward a reasonable solution. In principle, well-structured tasks tend to elicit less interaction among learners in the pursuit of a "correct" answer, while ill-structured tasks foster more in-depth discussion (Jonassen and Kwon 2001).

However, in our research on the design of mobile learning trails, we found that the degree of structuredness in task design does not sufficiently explain the differences in student engagement and interaction patterns. Instead, the degree of incorporating contextual variables, resources, and tools seems to better explain the observed differences (Tan and So 2011). By *contextual variables*, we emphasize that context in mobile learning does not and cannot remain constant, since learning "also creates context through continual interaction" (Lonsdale et al. 2003 in Sharples et al. 2007, p. 230) as learners move from one location to another. Mobile learning experiences can be enhanced with the identification, the analysis, and the incorporation of complex, unforeseen variables into task design. By *unforeseen variables*, we highlight the nature of complexity in situated learning experiences where learners have to manipulate multiple complex variables that may not remain constant but highly interact with other surrounding factors.

Based on this assertion, we conducted a retrospective analysis to examine the degree of embedding contextual resources and unforeseen variables in both mobile learning trails, according to the following three categories of task types (So and Tan 2014):

- *Performative task* tends to be close-ended and linear, such as simple application and procedural tasks.
- *Complex performative* task tends to be procedural but can be nonlinear and complex with incorporation of unforeseen variables.
- *Knowledge generative* task tends to be ill-structured, open-ended, and nonlinear, such as design thinking and creation problems.

On the whole, the retrospective analysis seems to indicate that the British Defense Strategy Trail was more successful in integrating complex performative and knowledge generative task types than the River Mystery Trail. Learning tasks in the River Mystery Trail did not sufficiently embed unforeseen variables and resources that were uniquely available in certain physical locations. Hence, the students appeared to perceive learning tasks as simply procedural and linear, where they could perform without much interaction with the physical environment. On the other hand, the design of the British Defense Strategy Trail integrated unforeseen variables and contextual resources in some of the learning tasks. For instance, determining the direction of the gun using the iPad compass is an example of *complex performative task* where students apply learned procedural skills, but answers are not straightforward as students have to consider multiple situational variables that might influence the gun's directions. Describing reasons for the British's plan to locate towers and guns in certain areas is an example of *knowledge generative tasks* where students have to examine and evaluate various information, physical objects, and resources in a given location to construct valid explanations. In sum, we advocate that complex performative and knowledge generative tasks are likely to increase the level of students' meaningful and active interaction in mobile learning trails.

Socio-technical Configuration for the Establishment of Common Grounds

We experimented with different collaboration structures and group sizes to facilitate student collaboration in each mobile learning trail. In the British Defense Strategy Trail, we used a small group collaboration structure where the students in groups of 3–4 members were formed and remained in the same group throughout the trail. The River Mystery Trail used a split-and-merge structure where the students in groups of four members formed two dyads to perform investigation beginning from two different locations and eventually merged at the final learning station as a group for collective problem solving.

Our overall observations seem to indicate that both small group and dyadic collaboration structures may not be productive if the structure fails to promote the establishment of common grounds. Student discourse and interaction in the small group collaboration structure were heavily influenced by group dynamics and the division of work. The students appeared to be rushing to complete the given learning tasks in a competitive manner. As such, the students adopted an efficiency-driven approach where they divided the work, and student ideas were rarely challenged or deeply discussed under this structure. Conversely, dyad collaboration under the split-and-merge structure at the Singapore River area appeared to promote a relatively high level of mutual agreement and engagement for pair work as we were able to see higher occurrences of collaborative talk between the two members. However, we also found that the split-and-merge structure may have some limitations when it fails to establish common grounds within and across dyads. It was observed that when merged at the central activity station, the two dyads were rather reluctant to share findings with each other for collective problem solving.

Regarding the observation above, we do not imply that there is an ideal group size as we believe the impact of group size is relative (Strijbos et al. 2004; Veerman and Veldhuis-Diermanse 2001). Instead, what seems more pertinent to the design of mobile learning trails is to investigate socio-technical configurations that afford the establishment of *common grounds*. *Grounding*, which is an interactive process of establishing and maintaining shared understanding between individuals, has appeared critical for defining the notion of collaborative learning (Koschmann and LeBaron 2003; Stahl 2006). Essentially, grounding involves *agents*, *tools*, and *goals* (Baker et al. 1999). That is, to establish and maintain common grounds, agents need to mutually understand goals, and tools are often used to mediate such a process. Applying the construct of grounding in our research context, agents refer to learners working on collaborative tasks. Goals can be perceived as both external and situational. *External goals* are those that were determined a priori by the teachers/researchers, whereas *situational goals* are more specific goals that learners generate in relation to situations where they are located. Such practices to gain mutual understanding of goals, whether they are external or situational, are mediated by both *material* tools (e.g., concrete objects) and *semiotic* tools (e.g., language).

Based on the notion of grounding, it becomes clear that tools, goals, and situation in the context of mobile learning undergo constant dynamic changes as learners are on the move constructing meanings while interacting with the surrounding environment. In our research context, as learners pursued macro-level external goals by completing the series of given tasks during the trail, concurrently, they created micro-level situational goals that were more specific to the surrounding environment that they were interacting with. This dynamic nature of mobile learning presents important implications to the design of socio-technological configurations. That is, technological tools for merely presenting and accessing information are not sufficient for the establishment of common grounds. There should be a mechanism to monitor the state of the other collaborators, groups, and facilitators and the provision of a platform to provide/receive feedback where necessary, as well as detect and repair conflicts when they arise (Baker et al. 1999).

In our research context, a Web-based platform called SquareCrumbs (see Fig. 17.3) was designed to facilitate the whole learning process. The platform embedded some mobile applications (e.g., digital maps) for students' navigations, and a public place "comments" where students could asynchronously communicate with each other and teacher facilitators, strengthening a collaborative learning space at a community level. While our design intention was to help students build common grounds within and across groups through the use of those technical tools, however, the Web-based platform was mainly used for accessing and receiving information.

As mentioned earlier, a number of the given tasks in our mobile learning context involved the use of complex, unforeseen variables that the students had to deal with in an ad hoc manner. Establishing common grounds for solving such complex problems is a progressive process. For instance, there was a need to position a technological platform that resided continuously in the intervals across pre-trail, trail, and post-trail activities. Hence, in the River Mystery Trail, we attempted to use another platform Knowledge Forum as a central socio-technological space where students collaboratively built knowledge throughout the whole learning process across different locations and time scales. While we found some positive effect of using such a central technical tool for continuous learning experiences, we also observed that many of the existing technical platforms are not well suited to help students establish and maintain common grounds for collective problem solving in mobile learning situations. According to Lemke (1999), there are two types of representations: *typological representations* which are mainly language-based and *topological representations* which are space-based and continuous. Based on our research experiences, we suggest that there is a strong need to design socio-technical tools that support both typological and topological representations. That is, constructing common grounds for effective joint activities is likely to be enhanced, when semiotic and spatial attributes of mobile learning activities are seamlessly supported through appropriate social structures and technological tools.

Discussion and Conclusion

In this chapter, we presented a retrospective analysis of the design and enactment of two mobile learning trails conducted in the context of a future school in Singapore. The main goal of this chapter was to identify critical design features and elements that influenced students' collaborative knowledge building during a mobile learning trail across multiple settings. In the past decade, mobile learning has gained much success in cultivating students' competencies in important skills such as critical thinking and collaborative learning. Yet, much of the existing research concerning mobile learning activities or activities involving outdoor learning with mobile devices tends to focus on the design of technological tools and systems, the evaluation of mobile learning services, or the measurement of cognitive or affective learning gains. There seems a lack of the knowledge base that can inform what kinds of instructional or learning design strategies should be used to support the design of mobile learning activities that explicitly aims to bring the potential of rich learning experiences that students gain in situated learning environments across multiple contexts, into the essential part of school curricula.

While "location matters" appears as a frequent account made for the justification of mobile learning, less is known about design principles, strategies, and factors (So et al. 2009). Almost two decades ago, Orion and Hofstein (1994) argued that

“The field trip is one of the most complex and expensive activities in the educational system. Therefore, it is important to achieve optimal educational results that will justify the investment” (p. 1117). We observe that the field of mobile learning is also facing the same issue where schools and teachers tend to perceive mobile learning as complex and expensive activities, which makes the justification of their investment difficult. Essentially, the design of the mobile learning trail should focus on how we can assist students to leverage the rich affordances of the authentic learning setting and to engage students in user-generated activities, thereby advancing prior knowledge and/or creating new knowledge with situational and contextual resources.

We argue that one way to move forward the field of seamless mobile learning research is to deepen our knowledge base by specifying the critical design elements and variables that must be taken into account. Thus, our attempt to look back and conduct a retrospective analysis of our design and enactment process was to deepen our understanding on why and how some of design elements worked or failed. The process to analyze socio-techno structures in design-based research is critical to understand important issues in designing learning environments with technology (Bielaczyc 2006).

In this chapter, we unpacked several design elements that appeared to influence and shape the impact of mobile learning activities on the learning process and outcomes. First, putting in place a pre- and post-trail phase is imperative to establish a learning continuum linking classroom and outdoor learning contexts. As surfaced in the preceding discussion, mobile learning trail(s) should not be perceived as an excursion or a 1-day field study, but it ought to be conceived of as a part of the larger curriculum. Further, a central task in design process is to support a seamless flow of learning across contexts, which requires a tight coupling of understanding main learning content, determining meaningful learning contexts, and facilitating continuity in the whole learning process. With the rapid adoption and integration of mobile devices, there is no doubt that learning spaces continue to expand by linking formal school learning and informal learning spaces. However, it is imperative to understand that although technological affordances and other factors are important for shaping students’ learning activities, the learning performance and outcome are heavily dependent on the activity design and teachers’ effective guidance.

Second, the design of mobile learning ought to see an effective combination of both designed and user-generated activities, which encapsulates both macro-level external goals and micro-level situational goals pertaining to the specific outdoor setting. The former serves as a preconditioning measure to reduce novelty space, and the latter affords an unstructured learning space where students can leverage on the rich physical affordances to pursue their own inquiries. However, the quantity, the range, and the type of designed activities would invariably rest on students’ readiness, the novelty space, as well as other factors such as the duration of trail and the ease of activity management. Hence, contextualizing mobile learning activities, as surfaced in our analysis, is critical as a measure of precondition for user-generated activities.

Third, it is imperative to provide “common grounds” to foster and to sustain collaborative knowledge creation and advancement across varying contexts and time scales. This serves to enhance continuity of collaborative discourse from the classroom to the outdoor and back to the classroom. Students need to see connectivity in order to integrate their learning experiences across multiple contexts and content. While our use of Knowledge Forum apart from the SquareCrumbs platform was engineered toward this larger objective, it would be more convenient and effective to provide a one-stop platform for students.

One important challenge that we want to surface from our design-based research experience is the need to consider the interplay between design/research goals and educational usage for it has serious implications on the design of mobile learning activities in educational settings (Milrad 2006). Indeed, whether mobile learning is reckoned as an effective platform to enhance teaching and learning beyond the four walls of the classroom is also an issue of larger institutional goals and directions. We found that teachers' perspectives toward the effectiveness of mobile learning tend to be highly influenced by the need to meet the school's curricular goals. This suggests that the curricular goals targeted in schools should be tightly intertwined within research objectives, without jeopardizing the interest of each stakeholder. Though curricular goals might sometimes constrain the type of resources or learning tasks in designing mobile learning activities, a balance between research and curricular goals should be made to reconcile potential tensions that may arise in research design and implementation.

We believe that our retrospective analysis presented in this chapter can serve to widen and deepen our knowledge base on the critical factors and elements for designing effective mobile learning activities arising from situated learning perspective. Through this retrospective analysis, we call for further design-based research that aims to develop more in-depth understanding of how and why certain design of mobile learning activities works or fails and thereby create comprehensive and specific measures to improve the design framework. This, in turn, would enable us to develop theoretically and pedagogically sound models to guide the design of seamless mobile learning.

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Chapter 18
Tell Your Story About History: A Mobile Seamless Learning Approach to Support Mobile Digital Storytelling (mDS)

Susanna Nordmark and Marcelo Milrad

Abstract This chapter describes our efforts toward finalizing an all-embracing workflow for a mobile seamless learning approach supporting mobile digital storytelling (mDS) for educational purposes. Considering the factors of locality, formality, and time as well as the design of the activity and assignments, we have chosen five dimensions of the mobile seamless learning framework to guide our work. In addition to the main mobile application used for mDS, we have also developed and integrated complementary software solutions well in line with the mDS framework, which support the overall learning experience. Here, we present our main three main pilot studies which have provided us with outcomes and insights on technical and methodological requirements, as well as on the importance of an active teacher involvement in order to introduce and implement ideas, inspiration, and routines from the mDS workflow into everyday educational practices. Applying the principles of design-based research (DBR) and codesign, we have collaborated closely with involved teachers and other stakeholders, devoting an extensive amount of time to introduce the five phases of the mDS workflow and the different technologies. The primary remainder of the challenges for concluding the mDS workflow will be to further refine all software components involved and to fully integrate them into one single social computing platform in which the chosen MSL dimensions and the learning activities in the different phases act as the interconnecting glue. This platform will also serve as a repository and a sharing option for all procedures related to mDS and the mDS activity outcomes.

Introduction

Our relation to the Internet is profoundly changing how we learn, communicate, and interact with each other. We live in a global society where digital artifacts are an essential and evident part of our everyday lives. The number of people utilizing some

S. Nordmark (✉) • M. Milrad
Center for Learning and Knowledge Technologies (CeLeKT), Linnaeus University, Växjö, Sweden
e-mail: susanna.nordmark@lnu.se; marcelo.milrad@lnu.se

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sort of online social media now exceeds the numbers using a more traditional media form (Nordicom 2012). Be it education, sport activities, rehabilitation, or play, information and communication technologies have come to play a central role in our way of relating to our physical, social, and cultural surroundings. The ongoing development of new and user-friendlier mobile technologies supports, amplifies, and speeds up these changes. Thus, the design, implementation, and deployment of innovative approaches for supporting new forms of interaction and collaboration, for example, the pervasive use of different social media, become a challenge.

In this chapter, we describe our research efforts conducted over the last 2 years, trying to address some of the issues described above through the design, development, and implementation of a mobile application and different Web-based tools with an accompanying workflow using the concept of mobile digital storytelling (mDS) in educational settings. In our hitherto studies (Nordmark et al. 2010; Nordmark and Milrad 2012a, b), we have identified a number of essential pedagogical and technological components and conditions that may serve as a basis for the creation of an mDS framework, i.e., a complete workflow and toolkit for introducing and supporting mDS methodology and technology in different learning contexts. We will mainly focus on describing the most recent stages of our designs and efforts while implementing the mDS workflow in authentic educational practices, where different stakeholders including schoolteachers, museum curators, researchers, and students have been involved in designing and trying out the activities.

This chapter is structured as follows: The next section introduces the notion of mDS and its associated challenges in relation to the presumptions introduced here. We describe the concept of mobile seamless learning (MSL) and how we have strived to integrate relevant MSL characteristics into our work. Thereafter, we describe the theoretical foundations that have guided our work, together with a short overview of related research efforts in the domain of mobile digital storytelling. The following section presents the design of our three main mDS studies, concluding with a discussion section presenting principal outcomes and plans for upcoming efforts.

Combining Digital Storytelling and Mobility

Since the dawn of mankind, we humans have told our past, present, and possible futures through stories, and there are no signs indicating that we will not continue to do so. The stories we share cover all conceivable areas of our lives – from our common history, traditions, and cultural heritage to the latest news, the dealings of the day, holiday experiences, childhood memories, school assignments, work projects, our plans for the future, and so on. However, if the contents and characteristics of our stories are more or less fixed, the modes in which they are conveyed have indeed changed over time. From imagery and carvings such as cave paintings, picture stones, and runes via the oral tradition of legends, songs, and drama to the more textual variations such as novels, poems, lyrics, papers, reports, essays, and articles, we have now moved on to the digital options, some of which with instant global reach: Web sites, blogs, tweets, and other social media postings, just to mention a few.

The concept of digital storytelling (DS) is a well-known storytelling method that offers excellent opportunities for anyone to creatively craft powerful stories, reports, and messages; for personal use and aims; as well as for various learning situations (see, e.g., Lambert 2007, 2013; Ohler 2007; Lundby 2008). DS smoothly combines still images, video, voice-over, and music with basic video editing features like transitions and panning, providing an end result similar to a film. However, a critical issue to note is that traditional DS is more or less a situated activity, meaning it has geographical boundaries limiting its potentials. It requires the use of a computer to which you need to connect a number of paraphernalia to transfer your images and record your voice-over. Moreover, you also need video editing software, audio recording software, and story creation software (provided that it cannot be accomplished within the video editor). Also, you cannot begin – or finish – creating your story regardless of your physical location; you have to access to your equipment first. This long-winded process risks interrupting the creative flow and preventing instant completion and accomplishment. Having access to mobile technologies when experiencing something somewhere could inspire and promote experiencing a sense of mobile seamless learning (Milrad et al. 2013), making the pupils participate and learn regardless of time, place, and support.

Mobile technologies are already an integral and well-established component in young people's daily lives (see, e.g., Ito 2009; Pachler et al. 2010; Nordicom 2012). The concept of mDS and its application to various learning contexts is a relatively new field of research. To bring the designs of digital storytelling to a mobile platform could offer unique affordances for meaning making, learning, and self-expression and also add possibilities for users to experience that seamless flow of learning experiences mentioned above. mDS would allow young users to participate, create, and share their "digital voice" by using a familiar tool that they consider to be their personal property, and perhaps also their foremost means for communication, a device they always carry with them wherever they go. Also, storytelling habitually encompasses a strong personal touch that is well in line with the intimate nature the ownership of a mobile phone carries, that special "love" we so often tend to develop toward it (Ito 2009; Pachler et al. 2010).

Therefore, bringing the mobile dimension to digital storytelling could provide unique opportunities for enacting and promoting mobile seamless learning experiences (Milrad et al. 2013). The ultimate goal would be to develop a versatile approach with a sound methodology and technological support for omnipresent access to creating, sharing, and learning across different context and learning situations. The concept of mobile seamless learning suggests that learners can learn constantly and ubiquitously, regardless of where, when, and how, effortlessly switching between these various learning scenarios by using mobile devices such as smartphones, tablets, or other mobile devices as mediators (Milrad et al. 2013). Wong and Looi (2011) have suggested ten different dimensions characterizing activities for MSL as described below:

> (MSL1) formal and informal learning, (MSL2) personalized and social learning, (MSL3) learning across time, (MSL4) learning across location, (MSL5) ubiquitous access to

learning resources, (MSL6) physical and digital worlds, (MSL7) multiple device type, multiple learning tasks, (MSL8) switching between multiple learning tasks, (MSL9) knowledge synthesis, and, (MSL10) multiple learning models.

For our current efforts on developing a workflow to support mDS, we have especially focused on the following six dimensions – MSL1, MSL3, MSL4, MSL7, MSL8, and MSL9 – which we believe are the most applicable in connection to our specific effort considering the factors of locality, formality, and time, as well as the design of the activity and assignments, together with access to mobile technologies. Section "Our Principal mDS Studies: Design, Outcomes, and Progression" will elaborate in more details how these MSL dimensions have been used to guide our efforts. In the next section, we present relevant parts of the theoretical background that guided our work, together with some interesting efforts related in the field.

Theoretical Foundations and Related Work

The traditional view on learning processes such as "transfer, remember, and recall" has been shifted toward "create, discover, interconnect, and understand ways to apply knowledge" (Sternberg 2006). Challenges for all levels of educational institutions therefore include exploring new ways to interact and to establish collaboration with researchers and designers working in the field of technology-enhanced learning (TEL) in order to create, adapt, and integrate modes and designs for learning (Nack 2010; Pachler et al. 2010; Selander and Kress 2010).

However, the challenges of integrating digital technologies and new ideas of methods and practices for teaching and learning in existing educational traditions still encompass several complex issues. These hindrances are widely reported, e.g., in a series of OECD reports by Pedró (2006, 2009), as a number of educational policies combined with local and practical issues, in the reports outlined as *technical*, *theoretical*, and *pedagogical issues*.

The technical issues involve having the proper equipment, infrastructure, and ongoing support in order to integrate digital technologies such as blogs, editing software for authoring digital stories, and so on. Whereas *the theoretical issues* deal with rethinking current approaches and models of learning and teaching and the history of the focus on the written word for school assignments, *the pedagogical issues* involve revising curriculum and welcoming ideas for renewal and deepening of teaching methods and questioning how to evaluate the learning gains but also how to deal with copyright, ethics, and such matters.

All of these hindrances impact schooling on all levels, such as how teachers decide on carrying out their everyday practice and how open they are to generally integrating a broader spectrum of multimodal texts in schools, and also in the examination processes of all formalized learning. The time factor is also a crucial issue here, since teachers constantly are given more and more tasks to accomplish, but with the same or often also a greater number of pupils, and the same demands on effective teaching hours. Therefore, teachers will need both extensive opportunities for exploring and experiencing how to integrate digital media and digital authoring tools in school and sufficient time for both the reflection on the pedagogical issues related and the implementation of new practices.

Today's pervasiveness of images is related to the ease with which many young people use and produce multimodal texts, such as how they edit and remix with digital software and distribute them, e.g., via YouTube, Instagram, and similar services. Speech and writing simply no longer suffice as sole means for understanding communication and meaning making. This paradigm shift toward the visual also gives rise to venues for the authorship of multimedia or "multimodal texts," a term that refers to text as incorporating different modes, including written words, sounds, gestures, mimics, poses, and images (Kress 2010). Here, multimodal refers to the growing research on media and meaning making in which designing a multimodal text refers to an expanded notion of text across different modes (Jewitt 2006, 2009; Kress and van Leeuwen 2001; Kress 2003, 2010; Selander and Kress 2010).

Kress (2010) effectively illustrates what multimodality is and what it implies for everyday learning and communicating. Even though many of his publications are written from a linguistic point of view, the concepts discussed in his work are widely applicable to a number of fields dealing with communication, learning, social studies, and design and are truly as cross-disciplined as the notion of multimodality itself.

Selander and Kress (2010) provide a fruitful outcome from many years of successful international collaboration. Their work discuss several issues close to Kress' *Multimodality* (2010), adding a specific focus on integrating and implementing multimodal design for teaching and learning, showing the reader what the multimodal approach implies for communication and meaning making in contemporary education, a need expressed to the authors by many teachers and pedagogues. Pachler et al. (2010) argue that mobile technologies and social media might be very well integrated into current school educational activities since they are transforming and defining new literacies outside of traditional education. One possible way to explore these new literacies is through applying a multimodal design approach to the use of mobile digital storytelling for collaborative learning.

As pointed out earlier, the application of mobile digital storytelling in educational settings is an emerging area for academic research, especially related to pedagogical issues on media literacy, teacher training, and the use of information technologies. In the remaining of this section, we point out a few similar efforts that have inspired our work on designing the mDS workflow and briefly discuss and analyze some of these efforts in order to contextualize our work. All efforts below relates to either one or more of our main areas of interest: storytelling, mobile technologies, formal and informal learning, history, and cultural heritage. However, none of the presented works fathom a full workflow for mDS, covering an mDS methodology and the associated mobile and Web technological tools to support it.

How factors of digital software and Web 2.0 social media may be changing patterns of stories is discussed in Alexander and Levine (2008) in the sense that stories are now open ended, branching, participatory, and unpredictable and may be revealing new directions for how we tell narratives, which is also discussed in Nack (2010) and Pachler et al. (2010).

Lombardo and Damiano (2012) have worked on developing a system supporting contextually aware storytelling units, using methods addressing both interactivity and movement to adapt the flow of stories as to how people actually move around in exhibition areas in a museum. In this case however, the system acted as the storyteller, not the user, delivering its stories to the mobile units depending on where the visitors chose to explore. Callaway et al. (2012) present another form of mobile museum systems that delivers slightly different dramatic stories on the mobile units to participants of smaller visiting groups, encouraging the group to share their experiences through animated discussions throughout the museum visit.

Druin et al. (2009) have developed a mobile storytelling application called StoryKit, focused on intergenerational storytelling, while Bidwell et al. (2010) have developed StoryBank, a mobile storytelling tool aimed at cross-cultural storytelling. Although these last two efforts have explored how digital storytelling can be used with mobile units to support aspects of formal and informal learning, none of the related efforts described in this section have investigated explicitly how to utilize mDS to specifically support and provide a mobile seamless learning experience in direct relation to the different MSL dimensions mentioned earlier.

As stated earlier, we are aiming at creating a set of tools and applications to support mDS that are guided by some of the MSL dimensions mentioned in section "Combining Digital Storytelling and Mobility". The research activities connected to these efforts involve different aspects of TEL design and implementation, innovative educational practices together with usability and sustainability, closely connected to several of the different dimensions of mobile seamless learning as described above. In the next section, we portray the design and setup of our main three mDS studies conducted during the last 2 years leading up to the full mDS workflow depicted in Fig. 18.1 below.

Our Principal mDS Studies: Design, Outcomes, and Progression

Aiming at a providing a mobile seamless learning approach that combines technology as well as methodology for users to design, organize, and undertake educational activities supporting an mDS workflow, we have focused our work on exploring the diverse desires and requests of the stakeholders involved. The main focus of our efforts have been aimed at the educational sector, given the fact that we are targeting said efforts toward the principles of mobile seamless learning, thus trying to provide the necessary prerequisites for the stakeholders to understand and appreciate these principles. Considering the requirements of our stakeholders, our theoretical foundations, and previous pilot studies, we have therefore integrated all parameters into the mDS workflow (Fig. 18.1 below).

The proposed mDS workflow consists of five interrelated processes that progressively build on each other, starting with phase 1, *Experience and Collect*, responding particularly to MSL 1, 3, 4, 7, and 8. In this phase, the pupils get their first

Fig. 18.1 Description of the mDS workflow, its phases, and the associated mobile seamless learning criteria (MSL)

acquaintance with the assignments ahead and are instructed to how to proceed through the full mDS workflow, and facts and impressions are gathered from the out-of-school events and assignments designed to inspire and motivate. Depending on the learning requirements of the relevant curricula for the events and the age of the study participants, a range of scripting approaches has hitherto been used during this phase, all from a narrowly defined story theme with closely supervised mind mapping and note-taking with clear instructions on how and when and how to use the mobile device to take photos and how to create and tell a story on that same device to a more self-regulated and problem-solving method for the gathering of the story constituents, together with an independent work process for the story creation session. The story data collection comprises the use of mobile technologies as well as more traditional tools such as post-it notes, pens, and paper. Phase 2, *Plan and Process*, responding in particular to MSL 1, 4, 7, and 9, encourages the storytellers to reflect on their experiences so far and to relate them and the materials gathered to their assigned story theme, by discussing what images to use, how to combine the chosen images with their script, in what order to tell their story, and what script to write for the voice-over recording. For this initial processing and planning part of the story creation session, the "less-is-more" rule is applied, instructing the storytellers to sift out whatever is superfluous when storyboarding and scripting. Here too, the storytellers use several technologies, of newer kind as well as a more traditional. Phase 3, *Create*, especially related to MSL 1, 4, 7, 8, and 9, invites the storytellers to use the mobile device with the preinstalled mDS application to insert, arrange, and edit selected images as planned and storyboarded in phase 2; record and edit voice-overs; add subtitles if needed; add a music soundtrack; add title and credits screens; use transitions; edit time settings; and preview the finished story. The pupils take turns in handling the device and in recording the different sections of the voice-over. Phase 4, *Store*, *Share and Present*, specifically responding to MSL 1, 4, 7, and 8, offers the possibility to store the finished story (the completed version and the each separate project file) in a designated Web repository; to share the story on, e.g., YouTube, by e-mail, etc.; and to review and present the story to an audience of some kind. The final phase, *Reflect*, *Remix and Reuse* (MSL 1, 3, 4, 7, 8, and 9), offers possibilities for story reflection and for story remixing and reuse.

A set of tools including mobile and Web technologies have been designed and implemented to support the different phases of the overall storytelling assignment as described in Fig. 18.1 above. In addition to the different solutions, all participants regardless of age have been offered complementary means of assistance, such as paper-based storyboard templates, notebooks, time management schedules, and a step-by-step guide designed for mobile digital storytelling.

In a series of studies basing our efforts on codesign (Spikol et al. 2009) and the principles of design-based research (DBR) (Ejersbo et al. 2008), we have tried to discern and outline what technological and methodological requirements guide users when engaging in mobile learning activities such as ours. Therefore, we have worked in close cooperation with the stakeholders of each study: the teachers, the pupils, the museum and cathedral personnel (providing the inspirational experiences), and representatives from school management.

Our three main pilot studies from Kronoberg, Bäckaslöv, and Ulriksberg, accomplished over a period of 2 years, are presented in detail in section "Our principal mDS studies: Design, outcomes, and progression". Figure 18.2 below displays an overall timeline of these efforts.

First mDS Pilot Study: Conceptualizing at the Kronoberg Ruined Castle (2011)

The Kronoberg pilot study was our first effort specifically aimed at testing the mobile format of digital storytelling by conceptualizing our theories and assumptions about mobile digital storytelling as a means for supporting learning regardless of context. We wanted to gain practice knowledge and to test the format as a first step. The study was designed as a 3-day intervention approach where we researchers took an active role in supporting the introduction of mobile digital storytelling, as well as hands-on training and practical matters concerning the realization of the activity. The study involved 24 children aged 9–12 and their teachers from a local elementary school in the south of Sweden. Other stakeholders involved were the local museum of Kulturparken Småland, a professional actor from the Växjö theater

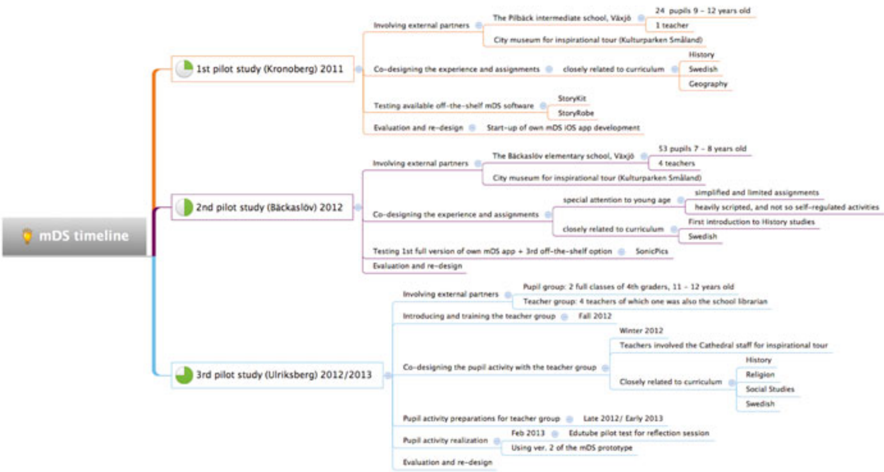


Fig. 18.2 The overall timeline of our mDS efforts

company, and the present authors from the Center for Learning and Knowledge Technologies (CeLeKT) at Linnaeus University, Växjö. The activities took place in the spring of 2011 in close connection to the ongoing studies in history, civics and Swedish and also as a part of a national effort on promoting outdoor physical activity for children. The outdoor events were located to the now ruined castle of Kronoberg,[1] which was once a stronghold part of the important defense line for the south Swedish border, strategically positioned by Lake Helgasjön.

By using one iPod Touch per group and a couple of off-the-shelf mobile applications supporting mDS, the objective for the school children was to collaboratively collect, create, edit, and produce their own stories of the castle, its inhabitants, and its surroundings, inspired by the various on-site activities provided by the museum personnel and by what they had studied in history class earlier. There were eight groups of three children in each group. Each child had singular responsibility for one specifically designated part of the story creation: (1) images/live content, (2) sound/voice-over, and (3) collection of facts, together with group activity documentation. Consequently, each group member took an individual and active part in the gathering of materials and in the production of the story. The documentation part was an attempt to make the pupils aware of and reflect on what choices and decisions they made and why during the creation process, issues they also had to address later when they reassembled for the story creation process, in which the children had to discuss, reflect, and argue for their ideas about the story theme and content, in order to make the final story a cooperative production representing the input from the whole group. Figure 18.3 below graphically outlines the 3-day activity.

For methodological support, a number of paper-based instructional aids were especially designed: a storyboard template; two easy-to-grasp software manuals,

[1] http://www.kulturparkensmaland.se/1.0.1.0/42/2/

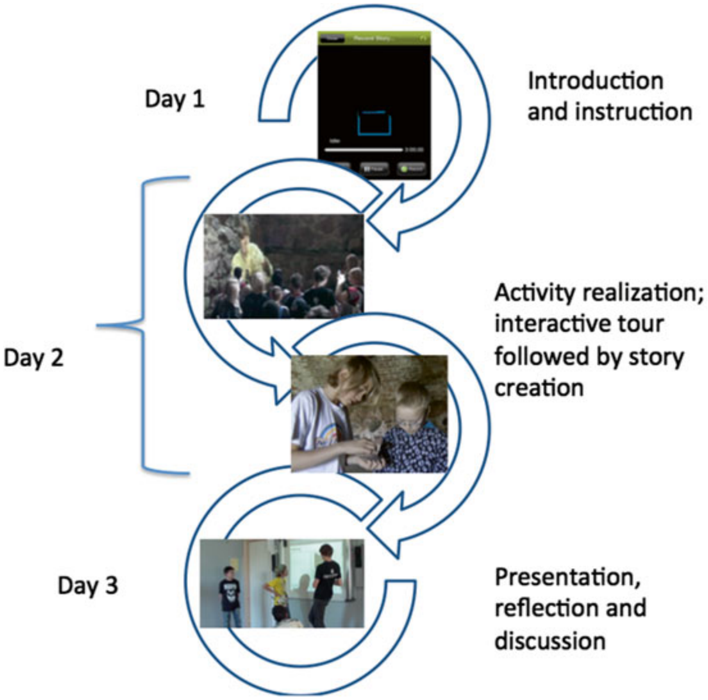


Fig. 18.3 The Kronoberg study overview

one for each application; a "Storyteller's ABC"; guide with short and clear instructions, suggestions, and explanations; and a set timetable for help and support with time management issues.

To set a baseline for the upcoming mDS application development, we used two different off-the-shelf applications created for mobile storytelling: StoryKit and StoryRobe. Both applications worked satisfactorily on an overall level but lacked in many of the basic but critical features needed for all kinds of mDS, e.g., easy step-by-step editing, providing audio tracks for both the voice-over and soundtrack. Also, many sequences took quite a while to finish, for example, the story compilation and video rendering parts, and through that process lacked to provide the user with information of either the estimated time up to finishing the task or continuous information showing that the process was still in action, all of these issues causing interruptions, irritation, and – in consequence – lost data.

As stated earlier, the primary goal for this pilot study was to gain practice knowledge and to test the format as a first step. Our intention when designing the study was to find indicators of learning regardless of context or setting supported by mobile technologies and to boost the understanding of multimodal approaches for self-expression and meaning making.

Based on the experiences and outcomes from this first pilot study, we identified that the existing mDS applications we used had a number of limitations making it hard for us to fulfill our overall purposes. Therefore, we initiated the design and development of our own mobile application for digital storytelling – the mDS application – to be used in our following studies. The primordial purpose for developing an mDS application of our own combined with an associated toolkit was twofold: (1) to provide users with services and functionalities not yet supported by other existing mDS applications and (2) to offer a complete workflow supporting the entire learning experience of mDS – from the initial learning activities, via relevant technical features and supporting tools, to an all-embracing Web service for sharing, storing, and retrieving stories, together with a collaborative editing feature for reflection, remix, and reuse of previously uploaded stories (Nordmark and Milrad 2012a, b).

Also, the concluding interviews with teachers and pupils also indicated a need for bridging the gap between informal and formal learning, which led us to incorporate structures from a theoretical framework supporting similar efforts of formal-informal learning contexts supported by mobile technologies, hence our subsequent focus on the MSL characteristics.

Second mDS Pilot Study: Local History with the Bäckaslöv School (2012)

As a consequence of the outcomes presented previously, we initiated the development of our own mDS application while simultaneously planning for the next study, which is presented in this section. To be able to offer the mDS concept as an all-embracing methodology for all stages of the compulsory school, we felt it necessary to try out the mDS concept and the first prototype version of the mDS application based on the needs of very young children. We also wanted to continue our collaboration with the local museum initiated in the previous study, and their already activated collaboration with the elementary school of Bäckaslöv therefore suited our intentions very well. Hence, this study came to involve 4 teachers and 53 primary school children (aged 7–8), researchers, and museum personnel. Shadowing their first ever studies in history and Swedish, the aim for the children was to get historically acquainted with their immediate school surroundings and to tell a story about one of the historical incidents, people, or locations they would experience during the activity day. Inspired by the ideas and theoretical concepts described in the previous sections, we strived to address and incorporate relevant criteria and aspects of MSL in the design of all activity phases, as presented in Table 18.1 below. It outlines and describes the activity phases and their settings, content, and assignments in relation to the relevant MSL characteristics.

Divided into groups of three, in day 1, the children initially took a guided outdoor tour led by a museum historian. Because of the young age of the participating pupils, the tour and its contents was augmented by using iPod Touch with a virtual guide application, visualizing an interactive aerial photograph of the tour.

Table 18.1 The Bäckaslöv study design

	Theme and setting	Researcher and museum staff activities	Teacher and student activities	MSL dimensions
Phase 1	*Introduction*, 60 min, @ classroom	Staff presentation, activity and assignment introduction | Mobile device introduction and software overview, mDS instruction | "Tour rules": when to photograph, when to open POIs, when to use mind maps, etc.	Presentation, discussion, questions	7,8,9
Phase 2	*Inspirational tour and mDS activity*, 5 h per day, @ outdoors	Division into workgroups | Repetition of software and storytelling instruction, repetition of tour rules, handout of mobile devices and mind maps | Run tour | Manage hands-on activities at museum grounds | Run storytelling activity.	Take tour: Photograph | Mind-map key words and take notes | Participate in hands-on activities | Accomplish mDS assignment: (a) Negotiate and decide story theme, (b) Select which photos to use, (c) Storyboard and script, (d) Run mDS app: add and arrange photos, add story title, record voiceover, preview, edit, finish.| Hand in device and materials.	1,3,4,7,8,9
Phase 3	*Concluding activity*, 2.5 h, @ school yard	Activity introduction | Run activity | Finish up: what happens next time we meet?	Collaboratively discuss, plan and create a physical time line of tour and stories, using a rope divided into time sections combined with images from tour app + images of own house + images from stories.	1,3,4,7,8,9
Phase 4	*Application evaluation*, 30 min per group, @ school	Activity introduction | Initiate and moderate usability discussion using app screen shots with smiley indicators.	[Groups A–I focus on mDS app Groups J–R focus on guide app] In groups discuss and answer a series of questions relating to the applications used during the tour and the storytelling activity.	1,7,8,9

(continued)

Table 18.1 (continued)

	Theme and setting	Researcher and museum staff activities	Teacher and student activities	MSL dimensions
Phase 5	*Reflective discussion on story content and work process*, 40 min per group, @ school	Activity introduction ∣ Initiate and moderate discussion using app screen shots with smiley indicators + post-it notes.	Watch all stories ∣ With focus on own story: Name 4 group views on the following components: image use, sound quality, theme relevance, and overall impression. ∣ With focus on all stories: (a) If you were to recommend your friends to watch these stories, how would you describe them? What would you say? (b) Discuss the following: If your group were to create a new story, would you do anything differently? If so, what? If not, why? (c) If you were to help some new group members create a mobile digital story, what would you tell them? What do you think is important to know and consider?	1,7,8,9

On the photograph, five points of interest (POI) chosen to complement the tour were indicated, each POI revealing historical images and sounds complementing the physical sites visited and the information shared by the historian. To support the story process and creation phases, all groups used mind maps for fact collection and memory support and the iPods only for photographing objects of interest. The story creation process was accomplished using the first version of the mDS prototype (HTML5) we developed.

Day 2 of the activity was conducted during an afternoon in the schoolyard (phase 3 in Table 18.1 above), and phases 4 and 5 were both concluded over two half-days.

In phases 4 and 5 of the activity (see Table 18.1 above), the children, teachers, and researchers met in a summing-up usability evaluation about the perceived benefits and disadvantages of the mobile applications and a reflective discussion about the story results and the overall work process. After completing all activity phases, we researchers lastly returned once more to the school to meet with the teachers and museum staff to discuss issues related to the story creation and production, technological issues arisen, the collaborative work process, and overall feedback from the realization of the activity.

The overall experiences from running this second mDS study combined with the outcomes from the usability tests conducted in activity phases 4 and 5 (see Table 18.1) supplied us with valuable feedback on as how to proceed with the next iteration of design and development in order to develop a fulfilling mDS workflow supporting the notions of mobile seamless learning. One of the most interesting lessons learned from working with children as young as these was they did not in fact encounter as many problems in handling the technology, as with coping with the overall mDS methodology, which after concluding study phases 4 and 5 stood out as the paramount obstacle for the children to overcome. Contrariwise, the general concerns of the participating teachers were focused on handling and mastering the technology rather than understanding the overall mDS workflow, which none of them reported having to struggle with. All teachers communicated a general need to learn more about mobile units and applications before daring to run any similar activity on their own, which for us was crucial information we took into close consideration when planning and designing for the next pilot study. For the technical issues and requests conveyed during the usability discussions, we devised a number of application redesigns, of which the two highest priorities were to get the voice-over interface stabilized and easier to handle and to integrate a contextualized help option, assisting each step of the story creation process. Also, two separate workflows were implemented: a basic alternative covering only the most essential mDS features and a more advanced workflow providing the user with a more substantial storytelling toolbox (see Appendix).

The focus of the third mDS study described in the following section was to test the consequences of the suggestions of improvement derived from this second mDS study, regarding both methodological issues and technical issues.

Third mDS Pilot Study: A Long-Term Experience at the Ulriksberg School (2012/2013)

Our previous studies have primarily provided us with outcomes and suggestions on technical requirements, methodological issues, and design considerations. However, the studies have also indicated a need for raising the bar of the overall technical knowledge, expressed by the participating teachers. Hence, our aims and objectives for the third study were twofold. Firstly, we obviously wanted to test the functionality of the latest version of the mDS application, but we also initiated the incorporation of complementary software solutions that we have developed, which are well in line with the mDS workflow proposed in this paper. Secondly, we tried to promote our participating teachers to introduce and implement ideas, inspiration, and routines from the mDS workflow and relevant MSL traits into their everyday educational practices, using a longer period of time for gradually introducing them to this way of working. The second aim relates to the earlier reported outcomes regarding the teachers' ownership and empowerment of the technology and methodology. It associates to the mDS assignment codesigned with us and is aligned with the pupils' subject studies and curriculum, ideas that are well in line with the notions of DBR and codesign referred to previously.

Our third mDS study was accomplished over a considerably longer period of time than any of our previous studies thus far, especially so for the teachers' part, stretching over a total of 1½ semester starting in the fall 2012. A total of 45 pupils aged 11–12 participated together with a team of four teachers, of which one also was the school librarian. The mDS activities were conducted in connection to the ongoing subject studies of history, social sciences, and religion, which at Swedish intermediate level is treated as one interdisciplinary study field. In the context of that study field, the team of teachers decided that the Cathedral of Växjö[2] was an appropriate object of study, since its history stretches over a thousand years and its establishment in this region was absolute imperative for the growth and expansion of Växjö as episcopal city.

What we aimed at accomplishing with the longer intervention perspective of this study was to provide the participating teachers with a sense of project ownership and feeling of mobile technology confidence, as well as with a solid understanding of the mDS workflow and its relation to the MSL dimensions. Thus, when the research effort ended, our intention was that the teachers would feel confident, inspired, and enabled to continue working with mobile learning technologies in some form, either with the full mDS workflow or relevant parts of it or with other aspects of mobile technologies for learning related to the concept of mobile seamless learning. In addition to the above, this extended period of project cooperation would also enable the teachers to take full responsibility for accomplishing a full cycle of the mDS workflow phases. With our support, they would take full responsibility for the planning, deciding, designing, and accomplishing of a complete cycle of mDS activities and events.

To supplement the 5th and last step of *Reflect*, *Remix*, *and Reuse* of the mDS workflow in Fig. 18.1 and to support our aims for incorporating complementary mDS-related software, an interactive Web-based video editor called EduTube (Kohen-Vacs et al. 2013) was added to the concluding reflection session. Consequently, in the final Ulriksberg pupil session, the EduTube system was used for enabling the children to watch, reflect, discuss, and embed their own questions into the finished stories, providing possibilities for additional learning dimensions. Our second and latest complementary technology, the collaborative interactive application for multi-touch surfaces and tangible interaction (Reski 2013) shown in Fig. 18.1, could due to overall scheduling issues for the pupils unfortunately not be assimilated to the workflow within this particular effort.

Part I: The Teachers

Throughout the mDS development and the subsequent studies, we have observed a significant risk for discontinuation of the efforts accomplished. When the research studies are completed, there simply are not enough incentives, personnel, or support in place to continue working with and further developing similar efforts, a state communicated by all teachers involved in our previous studies. For the third pilot

[2] http://sv.wikipedia.org/wiki/V%C3%A4xj%C3%B6_domkyrka

study, we therefore focused strongly on the "teacher-enabling" perspective by providing a series of discussion seminars and "previous-technology-experience-sessions" held over a longer period of time and with extensive information and support regarding methodology as well as technology, as well as on follow-up and evaluation sessions. The initial teacher meetings were focused on sharing previous experiences of technology-enhanced learning efforts and to discuss opinions, apprehensions, expectations, and suggestions for the upcoming cooperation, both from the researchers' point of view and from the schoolteachers'. The subsequent meetings were aimed at teaching the teachers about the mDS workflow and MSL framework, ways to design an mDS event, and how to handle the technology involved. Throughout the study, all teachers each had unlimited access to an iPod Touch with the prototype mDS app so that they could explore and test the mDS software at their own pace. The last of the meetings were spent on planning and fine-tuning the pupil activity. Figure 18.4 below outlines the teacher sessions graphically.

Part II: The Pupils

The design and implementation of the pupil activities for this 3rd pilot study was guided by the different learning activities described for each phase of the proposed mDS workflow (see Fig. 18.1) and the description given in Fig. 18.2 (see details of the 3rd pilot study). Figure 18.5 below illustrates the study setup together with the mDS workflow phases and MSL criteria throughout the pupil activities.

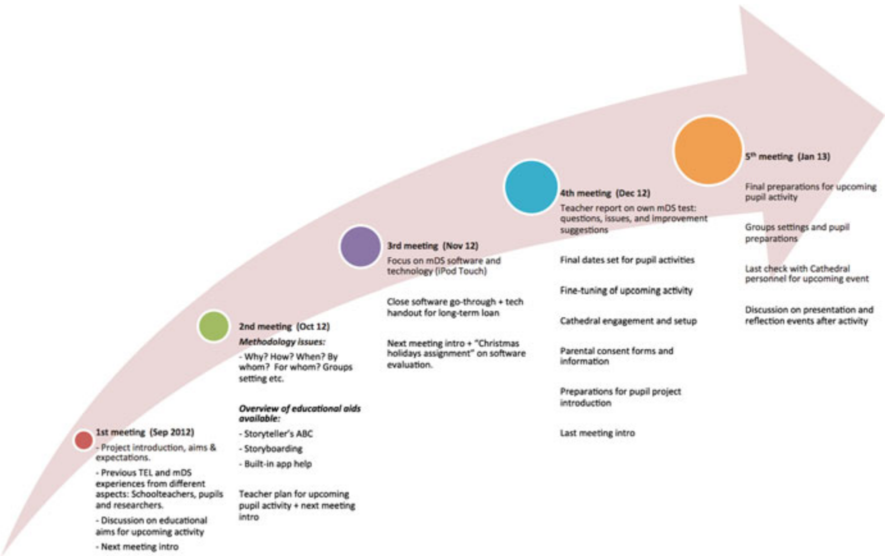


Fig. 18.4 Overview of the teacher sessions in the Ulriksberg study

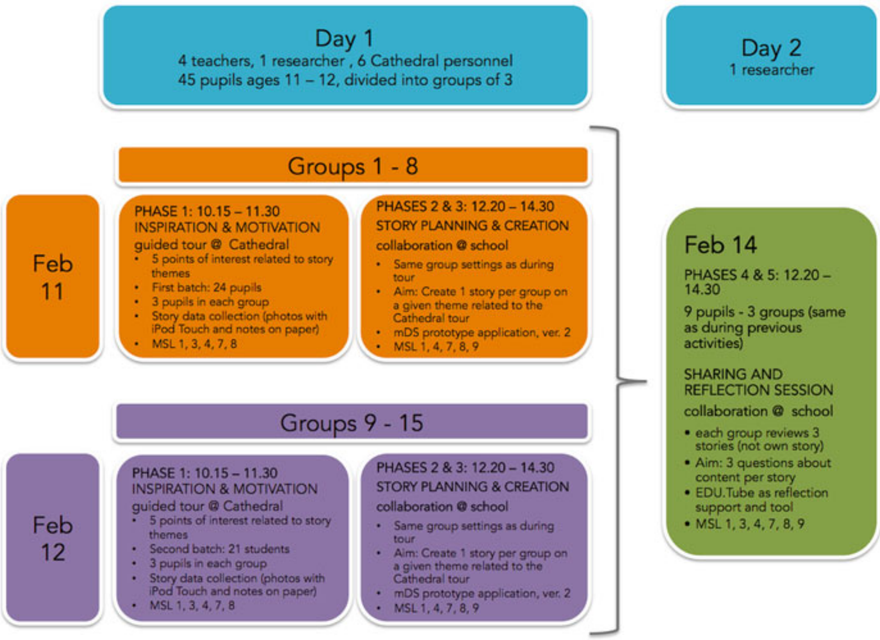


Fig. 18.5 Overview of the pupil activity design in the Ulriksberg study

The mDS activities for the pupils were conducted over 3 days in February 2013. For the cathedral tour and the following story creation process, the students were divided into groups of three, each group sharing an iPod Touch with the redesigned mDS prototype, now native iOS.

The opening cathedral tour was conducted by a group of cathedral pedagogues and one of the local vicars. The children and personnel were all in costume and traveled through the history of the Växjö and its cathedral by following an imaginative timeline through the church, starting outside by the Sigfrid sculpture and ending inside at the glass altarpiece. Each group of pupils had been given a story theme to pursue during the tour and finalize during the following story creation session. They had to collaborate on how and when to take notes and negotiate the photographing, before venturing onto the story creation process.

The story creation session started with a storyboard activity to plan and structure the story. Beneath each storyboard image, the groups composed and wrote down the voice-over scripts, a task that proved to be more difficult than what the teachers had anticipated. Scripting the voice-over to complement the chosen images and fit the assigned story theme is generally the part where pupils encounter most problems and where pedagogical support is needed. Therefore, a large portion of the teacher time went into assisting the pupils creating these scripts. Thereafter, the groups proceeded to work with their voice-overs. Here, we also encountered a number of glitches and problems with the 2nd version of the mDS prototype. Most of the issues encountered could be explained with a very recent iOS update that had been installed after the mDS prototype, which made some of the iPods stop working properly. After finishing the voice-over recordings and previewing the end result, the pupils were offered to try out the optional features of the mDS app. These features included adding credits screens, altering image transitions, changing the time settings, and adding of subtitles if needed and soundtrack if desired. The story creation session ended with a quick teacher check that all groups had finished their work adequately and that all groups had (at least) one finished and saved story on their iPods.

For the concluding reflective and discussion session, three of the pupil groups further elaborated on some of the stories by using the interactive video system EduTube. As described earlier, the EduTube system allows easy access to YouTube content, in this particular case the shared mDS stories from the cathedral session. EduTube allows review and reflection of the stories and interactive posing of questions and statements for peers to discuss and solve. Each group had three stories to watch and discuss. They were instructed to reflect, comment, and create at least three relevant questions on the content of each story by incorporating their work in EduTube. After a short introduction to the EduTube system and the assignment, the groups started working. All three groups handled the system without major difficulties, granting the participating pupils a deeper insight to what other groups had accomplished and shared. In the end, all but one group managed to create the three questions required for each story. The group defended the failure due to time management issues, which was a fully acceptable reason, regarding the limited amount of time available.

What also could be noted from the EduTube session was the pupils' overall interest for creating tasks for their peers to work with. Listening in on the discussions around the tables gave us the impression that this session really captured their interest and motivated them to fulfill the assignment, in particular related to the notion of knowledge synthesis (MSL9). Figure 18.6 below shows some of the pupils running the EduTube system.[3]

Discussion, Outcomes, and Upcoming Efforts

This chapter has described our efforts toward finalizing a complete workflow for mobile digital storytelling supported by the concept of mobile seamless learning. Our intention of incorporating our associated stakeholders in the codesign and development of the mDS toolkit and methodology has provided us with valuable insights on what our fellow users' – pupils, teachers, and other learning professionals – estimates and values when deploying educational activities of this kind. Each study has functioned as means for reiterated design efforts for the mDS methodology and software, leading to relevant alterations, enhanced software design, and

[3] http://edutube-hit.telem-hit.net/

Fig. 18.6 Pupils creating story questions in the Ulriksberg EduTube session

methodological improvement. Each study was concluded with intense and penetrating reflective and evaluative discussions involving pupils and teachers, either in combination or as separated groups. All pupil interactions were videotaped, and the pupils' complete working materials (storyboards, scripts, etc.) were collected and evaluated in collaboration with the teachers involved.

In our first two major studies, the main outcomes were accumulated around two main themes: software requirements and development and the need for extensive teacher support (Nordmark and Milrad 2012a, b). Also, the importance of location and informality was manifested, compelling us to focus on and integrate relevant MSL criteria into each study phase and the mDS workflow, adapting and transforming some of the MSL dimensions into practical design actions.

Since the first two studies also established a need for the participating teachers to know more about mobile technologies for learning, a need explicitly expressed by the teachers themselves, the third study came to focus on teacher comfort and acquisition around mobile technologies, assignment design, and mDS methodology in relation to MSL and brought us further insights on how to transfer project-oriented mobile learning efforts into more sustainable features of teachers' everyday practices. Even though the third study was conducted over a considerably longer period of time, it nevertheless indicated that to empower teachers to fully embrace mobile learning technologies in their everyday practice, there still has to be some initial spark with expert initiative, involvement, and support to get everyone going and to provide an overall feeling of confidence throughout the process to provide chances of continuation. Our latest efforts on finalizing the mDS workflow have also launched the integration of additional technologies supporting mDS, offering an expanded range of working methods for mDS (Nordmark and Milrad 2014).

The uniqueness of the above-described efforts can be seen on several levels, the latest being the integration of a set of new and complementary mDS-related technologies, each with a commission of its own, but that – when combined with the mDS workflow – provide new learning opportunities and variations to the mDS methodology. Thus, our intention of introducing and integrating the mDS workflow with relevant MSL dimensions and complementary technologies into teachers' everyday practice, linking the formal learning environment of school to the informal everyday circumstances children and young people experience, could provide additional learning possibilities and motivational boost.

In each of the above-described pilot studies, conveyed in the concluding reflective and evaluative discussions, we and the teachers together observed intensified motivation and overall higher activation levels among their pupils and especially so for some of the children that before had shown low or no interest in participating in the everyday schoolwork. Of course, these effects could be explained by the extracurricular happenings and the excitement activities like these tend to bring, but the teachers – who undoubtedly knew their students a lot better than we got to know them – maintained that they experienced heightened levels of commitment, focus, and interest, which they believed were linked directly to the extensive learning opportunities the mDS workflow and the integrated MSL notions provided, where MSL supported not only various learning styles but also an actual sense of continuous learning regardless of location.

The next step on concluding the mDS workflow described in this chapter will be the last redesign of the mDS iOS application to further refine the current versions of the complementary software solutions involved and to concentrate on the challenge of fully integrating all complementary technologies into one single social computing platform, where the different MSL dimensions and the learning activities at the different phases act as the interconnecting glue. This platform will also serve as a repository and sharing option for all activities concerning mDS and its related activity outcomes, as described in Fig. 18.7.

For our upcoming fourth mDS study, we will collaborate with a school already fully "mobile," meaning that all teachers and students are not only encouraged but requested to use tablets, computers, smartphones, and other similar equipment throughout. We will certainly get a chance to test the validity of the experienced motivational and committal factors reported earlier. Here, the students will not be overwhelmed by the sudden access to previously inaccessible technologies and events but instead have the possibility to focus more on the processes and outcomes of mDS supported by mobile seamless learning.

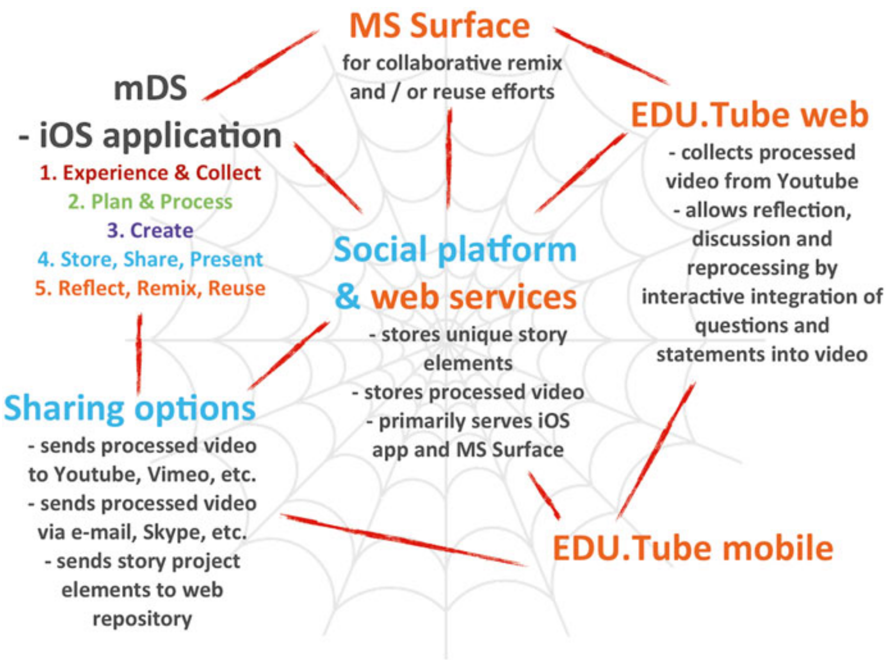
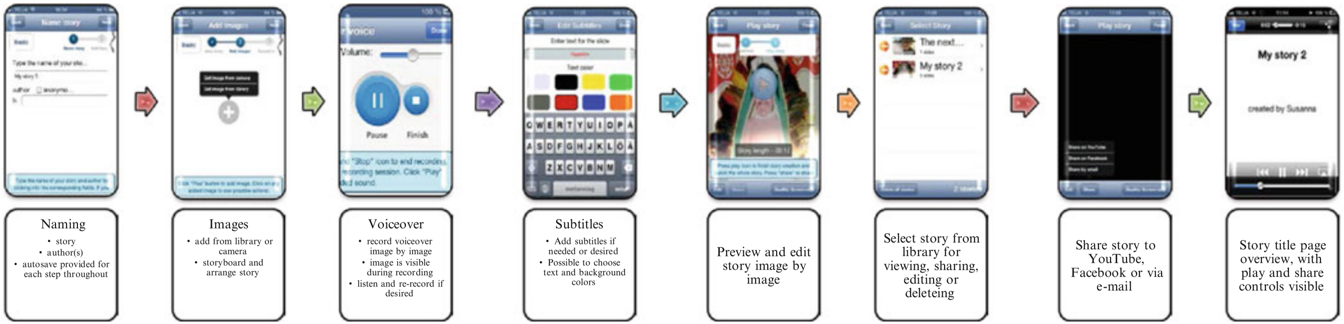


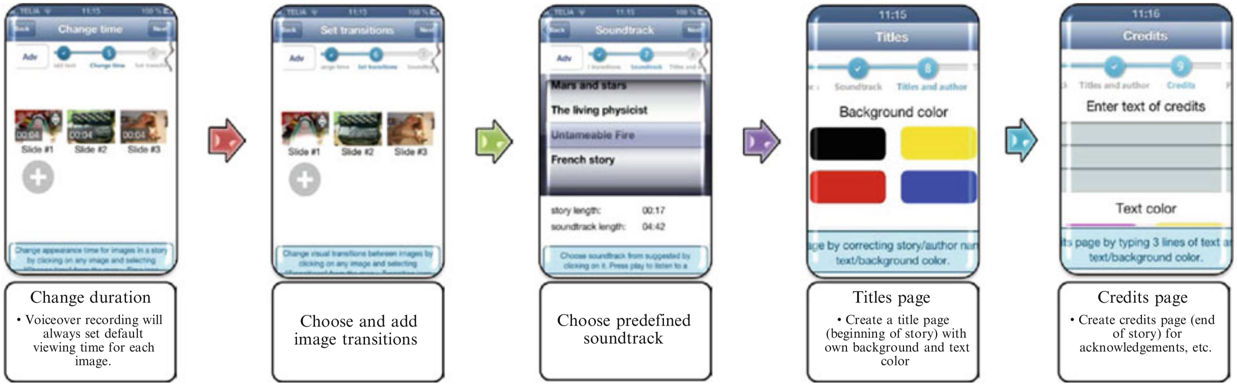
Fig. 18.7 The full mDS toolkit with mobile and multi-touch mDS applications, reflection and discussion tools, and a social media and repository Web provider

Appendix

The basic options of the prototype mDS application:



The advanced options:



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Chapter 19
Challenges and Approaches to Seamless Learning in Security and Defense

Christian Glahn

Abstract Professionals in military and international humanitarian organizations increasingly have to perform under unstable conditions in dangerous environments during crisis and emergency response missions. Therefore, every professional in these organizations requires continuous training and development. While information technology has made a valuable contribution to satisfying the organizational and professional needs, there are many seams between the different activities and tasks as well as between the technologies that are used to support professionals. This chapter addresses the underpinning conditions and the design of mobile solutions for bridging the seams of technology support in professional education and training in the security and defense sector. This chapter analyzes the domain-specific conditions and seams for using mobile learning solutions in professional development and maps them onto those that were previously identified in formal public education. This mapping helps guiding the development of new concepts and solutions for seamless learning in professional education and training, which is illustrated by analyzing four application cases of mobile seamless learning in order to map the state of existing solutions and to identify gaps for further research.

Introduction

Chan et al. coined the term "seamless learning" as a continuum of learning experiences across different environments and meld them into a transient learning environment (Chan et al. 2006): "seamless learning implies that a student can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using the personal device as a mediator." To security and defense organizations, mobile technologies offer new and flexible ways to prepare professionals for their mission tasks by developing their "21st century skills" through learning in and across contexts (Sterling 2011). Recent smart technologies are of special interest for security and defense organizations because they offer high

C. Glahn (✉)
International Relations and Security Network, ETH Zürich, Zürich, Switzerland
e-mail: christian.glahn@sipo.gess.ethz.ch

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processing power, while they only add a relatively small overhead to the infrastructure requirements and the personal equipment. This makes mobile devices the ideal medium for in-mission training and learning that also offers opportunities for easing out the seams between the different educational technology approaches.

The uptake of mobile technologies in security and defense organizations is often limited to battlefield support (Sterling 2011), despite the high potentials of mobile technologies, the general consumer adoption of these technologies, and the demand indications in organizational market data (Glahn 2012a). Security and defense organizations will have to respond to this demand rather sooner than later, partly because of the changed expectations of their personnel towards mobile services and devices and partly because of the increased need for professional education and training. This chapter analyzes the challenges for introducing mobile seamless learning into security and defense organizations and how different approaches address these challenges.

Professionals in military and international humanitarian organizations increasingly have to perform under unstable conditions in dangerous environments during crisis and emergency response missions. Therefore, every defense and security professional requires adequate training and development to ensure that they are capable of adapting to the complex conditions of their missions (Sterling 2011). For many years, information technology has made a valuable contribution to satisfying the organizational and professional needs in the security and defense domain in response to crises. Crisis response missions typically have a strategic and a tactic component with the related technological tools in the form of mission support applications and battlefield solutions (Çayirci and Marincic 2009). The specific information needs in crisis response mission in the security and defense sector are essential elements, which is why these organizations are among the early adopters of ICT solutions.

Responding to crises is a relatively small part of the organizational practice in this sector, while pre-mission activities are more common in the daily routine. Four categories characterize the activities of security and defense organizations: combat and emergency response, mission support, management and operations, as well as education and training. Mobile solutions are well established for dynamic in-mission scenarios (Jones 2012) but become available for mobile pre-mission activities with a significant delay (Sterling 2011). The pre-mission activities typically include preparation and training for professional tasks, career development, as well as the organizational operations. For each of the four categories, different ICT solutions are available for addressing the specific task-related needs. Within education and training, these solutions include online self-study course modules, simulations, virtual worlds, as well as social and collaborative online learning activities. These solutions augment and partly replace conventional face-to-face training. In the literature, these activities and tools were referred to as "military education" (Sterling 2011; Çayirci and Marincic 2009), but due to the broadened understanding of security (Cope 1995) they are also part of security education of nonmilitary organizations. Therefore, this chapter uses "security and defense learning" (SDL) to refer to this special form of vocational education and training without limiting it to the scope of "military education" (Jung 2007) or "military pedagogy" (Royl 2005).

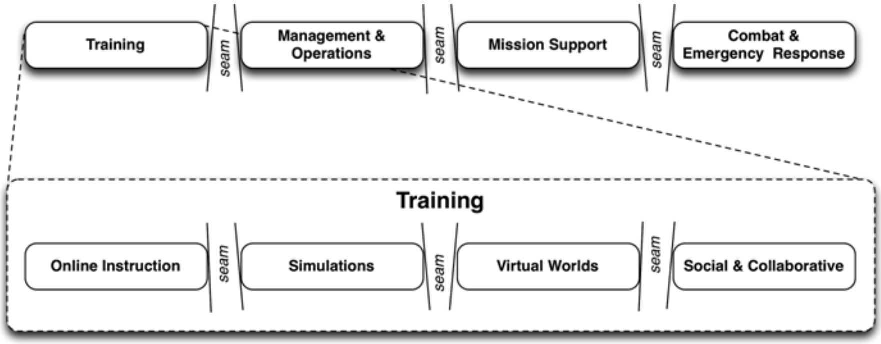

Fig. 19.1 Activity areas and seams in security and defense organizations

Using ICT in security and defense organizations is by far not seamless. Across the different activity areas there, it is often difficult to integrate solutions, but also within each activity areas, the different ICT solutions are not necessarily well integrated. This creates seams in the professional practice as well as in the related education and training (Fig. 19.1). These seams have three characteristic factors that need to be considered for bridging them: firstly, the availability of the technology for all sides of the seam; secondly, the organizational and often legal constraints of implementing new technologies for multiple purposes; and finally, the interoperability and connectivity of technologies in different settings (Glahn 2013).

SDL is currently affected by two developments. Firstly, professionals are more frequently involved in complex humanitarian and military missions. Secondly, the context of the professional practice itself has become more complex and is subject to frequent changes. Both developments require frequent learning and relearning of professional skills and competences. This becomes increasingly necessary during missions but can sometimes take place only afterwards due to the constraints in the organization of education and training. In long-term deployments, staff is required to travel in order to further develop their task-related competences and skills. However, such travel implies increased exposure to risk and effectively reduces the time spent for professional further education.

The so-called "advanced distributed learning" (ADL) partly addresses the new SDL challenges. These solutions often replace conventional face-to-face training units by applying open and distance learning (ODL) concepts in web-based learning environments (Bonk and Wisher 2000; Starr-Glass 2011). These approaches encourage self-regulated learning that is independent from a learning schedule as well as from the learners' location. This is also known as "anytime-anywhere-learning," which is a core underpinning for using ADL solutions in SDL. Moreover, ADL offers great benefits for standardizing and distributing of information on a large scale beyond the cost-savings argument (Sterling 2011). However, web-based solutions are optimized for special infrastructure that is difficult to provide under the field conditions. These solutions are less frequently used for specialized subjects with small target audiences. For example, simulations and virtual worlds are more frequently tailored for specialized subjects by extending preparatory face-to-face trainings that are hardly available to distance learning settings.

Conditions of Professional Learning and Training in Security and Defense

Security and defense organizations are host to many professions. These are required for running complex emergency operations (Çayirci and Marincic 2009). SDL needs to consider four levels of complexity in order to prepare professionals to adapt and respond appropriately in operations.

- Subject matter complexity
- Internal complexity
- Structural complexity
- External complexity

The *subject matter complexity* in security and defense organizations refers to professional ethics, operational regulations, and national legal compliance. Additionally, communication competences and advanced legal knowledge is increasingly required for successful operations in the field. The content for such knowledge and competencies does not necessarily form a logically coherent framework that can be immediately applied to practice.

The *internal complexity* of security and defense refers to organizations hierarchies, procedures, and integration of different professions. Furthermore, many organizations implement special security and communication protocols. The internal complexity is typically subject to standardization. These aspects are required for effective and efficient field operations, but they are not necessarily related to the professional subject matter expertise.

The third level of complexity is the *structural complexity*. This complexity type is related to the structures that are found in many organizations. Further, security and defense learning programs have to consider the spatial distribution of the organizations' staff, which is often distributed across many locations, regions, and even national states. This makes travelling time consuming and reduces the available learning time while it increases the costs. Additionally, emergency operations are typically not located near training facilities and travelling to in-mission training can expose the personnel to additional risks.

The *external complexity* refers to conditions that are typically outside the organization's control. This includes legal frameworks, political settings, relations to and alliances with other organizations as well as social, cultural, and geographic conditions. Professionals find themselves in settings in which each operation and project has its unique constraints regarding the political or functional mandate, social and cultural dependencies, and security status. In many cases, these constraints are unstable, dynamic, and difficult to predict.

The multidimensional complexity of the organizational practice creates unique working conditions for security and defense professionals. Therefore, organizations are responsible to enable their staff to adapt to the complexity and risk exposure of complex emergency operations. Such professional education is essential regardless whether the organization is governmental or nongovernmental, operates on a national or an international level, or has a humanitarian or military background. Consequently, organizational education and training has to develop a set of core competences in addition to the professional skills. Sterling (2011) identifies nine fundamental competences for twenty-first century security and defense personnel: (1) character and accountability; (2) comprehensive fitness; (3) adaptability and initiative; (4) lifelong learning skills and digital literacy; (5) teamwork and collaboration; (6) oral, written, and negotiating communication and engagement; (7) critical thinking and problem solving; (8) cultural and joint, interagency, intergovernmental, and multinational competences; as well as (9) tactical and technical competences. In order to develop these competencies, any organizational professionalization effort needs to address these five challenges.

- Diversity
- Heterogeneity
- Continuity
- Variability
- Standardization and interoperability

Diversity refers to the range of different professions that interact and work together. At this level, two types of education and training are relevant to most organizations: performance support and career development. Performance support refers to the knowledge and competencies that are required to effective and efficient actions in the field. This kind of training is often centered on the task description of a person. Career development focuses on building the personal capacities. This part of professionalization is a central aspect for promotion paths within the organization and for providing employment opportunities after leaving the organization.

Heterogeneity refers to the range of educational approaches, tools, and systems that are used for professionalization with an organization. Depending on the task description, different approaches might be relevant or available to the learner. This affects educational solutions, because of the heterogeneity of approaches and technologies that are used by the organizations in addition to web-based training approaches. For example, many defense organizations host complex simulators for practicing the operation of vehicles and equipment. The most prominent examples for such simulators are flight simulators. Other units use virtual world simulations for analyzing strategies and tactics.

Continuity is a challenge of security and defense learning because the acquired knowledge and competencies cannot always be applied immediately. Often there are significant gaps between the time of learning and the moments when this knowledge is required in practice. Therefore, relearning and intensifying of prior knowledge is part of the education and training strategy of many organizations.

Variability of the training approaches is required for aligning to the different settings in which security and defense professionals work and learn. Professionals find that their roles and the scope of their work changes between operations. Part of the organizational education and training objectives is the timely preparation for their tasks and for the operational contexts. For long-running operations, organizations need to provide education and training services to their members in the field, without exposing them to additional risk.

Standardization and Interoperability are of great importance to all organizations in this domain in order to integrate tools and technologies into existing structures and procedures. Standardization includes unification and the transparency of the educational objectives, the didactics, and the assessment procedures across courses. More recently this also includes the transparency of achievements beyond the organizational boundaries, for example, to connect to international standards for professionalization and academic degrees, such as those initiated by the Lisbon objectives or the Bologna Process in European higher education. Interoperability refers to the seamless interplay of different systems or of the system components. In the area of education and training, interoperability is often considered as the loose coupling of digital educational material and electronic delivery platforms. However, more recently, interoperability is more widely understood as the interplay and the data exchange between services, devices, and systems as well as the integration of technology-enhanced learning with presence-based education and instruction as an extension to the concept of blended learning.

The complexity dimensions and the educational challenges suggest that mobile solutions can significantly enrich the educational tools that are available to education and training in security and defense organizations. However, in order to provide viable solutions for mobile seamless learning, it is necessary to understand the seams that are present in this sector. In order to answer this question, 40 ADL experts from international defense colleges and academies discussed the barriers for mobile SDL solutions in a structured group discussion at the 2012 PfP ADL Working Group meeting in Vienna, Austria. The experts identified five distinct seams that mobile learning needs to address (Glahn 2013, p. 71ff).

SDL 1. Bridging between theory and application
SDL 2. Existing security regulations as well as security and cryptographic requirements
SDL 3. Mobile data connectivity, device availability, and financial constraints
SDL 4. Interoperability of device features and interoperability with existing infrastructure
SDL 5. Integration with existing educational practices

The most prominent seam for education and training for performance support is bridging between theory and practice. Many security and defense organizations implement complex education and training programs for the professionalization of their members. This includes classroom-based theoretical activities and training in the field. Additionally, simulators and virtual worlds are used for practicing more complex scenarios. Instruction on theories, practicing, and the application of knowledge in the field are often temporarily or spatially disconnected. This makes it difficult to identify misconceptions, conceptual gaps, or additional training needs.

The second seam of mobile learning lies within the existing *information security policy of security and defense organizations*. Mobile technologies raise a number of challenges for existing policies. These range from the carrier networks that are used for data transmissions of varying classification levels to the access to mobile information technologies within military facilities and their use for education and training. Large differences exist between the organizations at the level of specific regulations, but what they have in common is that most ICT-related security policies were not designed to respond to the increasing availability of mobile handheld and personal devices. Although such regulations are typically unrelated to education and training, they have direct impact for implementing mobile learning. Closely related are the *cryptographic requirements for data transmissions and data storage*. As mobile learning requires data exchange between mobile devices and the organizations' infrastructure, it raises questions regarding protecting organizational information.

Given the rapid growth of mobile data communication, many security risks of mobile technologies are either unknown or the understanding of security implications is in its infancy. One prominent example for this situation was the unrestricted access of installed apps to the contacts and calendar information on devices running Android, Blackberry OS, and iOS. This function has been present in these systems at least since 2007, but it only received major attention in 2011 after it became public that many app developers "harvested" addresses and calendar schedules for customer profiling even if the respective app did not require this information. This incident indicated that this form of data exchange between applications on personal devices has not been considered as a security threat, although all affected platforms already provided strong cryptographic features for protecting application data against other forms of unprivileged access. This illustrates that the cryptographic requirements are not limited to data transmission but extend to storing and processing data on mobile devices.

The organizational security requirements influence also the use of mobile devices in inter-organizational cooperation due to *different and potentially contradicting security protocols at the level of national organizations and international*. In order to take full benefit of mobile learning, it is necessary to analyze how these protocols can be aligned and standardized in order to enable the development of interoperable education and training services.

The third seam is related to the hardware for mobile learning, both at the level of the devices and of the network infrastructure. For mobile learning, this seam is related to the *wireless network infrastructure in military facilities*. This infrastructure is mandatory if access to information services has to be independent from private sector partners. Two aspects require attention at the level of the infrastructure: firstly, wireless network infrastructure is not available in all facilities and secondly, where the infrastructure is available, it is not clear if and how it can be used for education and training purposes. This poses a barrier for mobile learning because the related educational scenarios rely on wireless data transmission at some point. Furthermore, the device features as another barrier. Two aspects are relevant with this respect. The first aspect involves the definition of mobile devices. The second aspect refers to the operating systems that are installed on mobile devices.

Less than 10 years ago, mobile computing was mainly referring to laptop computers, while there are at least three major device types for mobile ICT relevant today: smartphones, tablet computers, and laptops. "Netbooks" and "PDAs" were also discussed as independent device classes. Each of these device types is clearly representing aspects of mobile ICT that distinguish it from the other types. Near-future predictions in wearable computing indicate further diversification in this segment. Therefore, it is difficult for organizational stakeholders to specify the key characteristics of mobile devices for educational purposes. This creates a barrier for mobile learning and ADL because *it is unclear if mobile learning has to be optimized for a specific type of device, or if all classes need to be supported at the same time*.

The second aspect related to the device characteristics is related to the *limited interoperability between mobile operating systems*, which challenges the sustainability of investing in developing educational material for mobile learning. For the development of mobile ICT solutions, at least eight relevant platforms have to be considered, compared to three platforms in desktop computing. These platforms are tightly coupled to the devices on which they are preinstalled. Unlike the situation in desktop computing, it is typically impossible to install a different mobile operating system on a mobile device. Even updating a mobile device to a new major release of its operating system can be difficult or even impossible. The participants noted that the increasing success of HTML5 technologies holds the potential for overcoming this barrier. However, they also expect that their organizations will face a very diverse distribution of mobile operating systems.

Related to the wireless network infrastructure in security and defense organizations is the barrier of *device availability and financial constraints of education and training departments*. In the private sector, particularly smaller organizations follow a "bring-your-own-device" (BYOD) strategy to mobile ICT. While this has the benefit of cost savings by relying on the infrastructure that is already in the hands and pockets of the staff, this path is difficult to follow for security and defense organizations due to the lack of controllability of information access. Yet, many organizations are unaware of the availability and distribution of privately owned mobile in their organization. The alternative to BYOD is to provide all members of the organization a mobile device, which will in return cause major financial investments in devices, infrastructure, and solution development. Such investments require an overarching organizational strategy because they are beyond the scope and financial capabilities of educational departments.

Finally, the *integration of new mobile learning concepts into the existing educational practice* poses a major barrier for mobile learning. This addresses the seam between different modes of learning and the related didactic approaches. While many stakeholders agree that mobile learning holds great potential to introduce new concepts for motivating and engaging learners in informal settings, the assessment and certification of non-formal and informal learning experiences remains a major challenge. Casual learning, "gamification," and mobile simulations were discussed by the participants as ways of making learning more attractive, but it was unclear whether these new approaches are compliant with the legal requirements for certification and recertification within and across organizations. The experts suggest that this requires a detailed analysis of mobile learning approaches with respect to the compliance of national and international regulations and policies.

The ubiquitous access to information and learning opportunities has not been discussed explicitly. This can be explained by considering that “anytime-and-anywhere” learning is a core aspect of ADL applications in SDL. Consequently, the ADL experts expect that mobile learning solutions provide at least the same level of flexibility with this regard.

Seamless Learning

Wong and Looi (2011) analyzed the literature on mobile seamless learning (MSL) in order to structure the underlying dimensions of MSL. The objective of this research is to inform researchers and practitioners in refining their learning designs. Consequently, the review does not include an explicit organizational perspective. The review of 54 research papers identified the ten overarching features/dimensions of MSL.

MSL 1. Encompassing formal and informal learning
MSL 2. Encompassing personalized and social learning
MSL 3. Across time
MSL 4. Across locations
MSL 5. Ubiquitous knowledge access
MSL 6. Encompassing physical and digital worlds
MSL 7. Combined use of multiple device types
MSL 8. Seamless switching between multiple learning tasks
MSL 9. Knowledge synthesis
MSL 10. Encompassing multiple pedagogical or learning activity models

While Wong and Looi (2011) focused their analysis on the published research, an independent expert study by Börner et al. (2010) aimed at identifying the grand challenges for mobile learning research (MLR). This study applied collaborative concept mapping for structuring problems and challenges in the multidimensional domain of mobile learning. The study identified the following clusters of research challenges:

MLR 1. Access to learning
MLR 2. Contextual learning
MLR 3. Orchestrating learning in and across contexts
MLR 4. Personalization of learning
MLR 5. Collaborative mobile learning
MLR 6. Mobile learning technologies
MLR 7. Organizational aspects for implementing mobile learning

Table 19.1 Mapping of MSL dimensions (Wong and Looi 2011) with MLR challenges (Börner et al. 2010), unmatched concepts highlighted by the *gray* background

	MLR 1	MLR 2	MLR 3	MLR 4	MLR 5	MLR 6	MLR 7
MSL 1		X	X				
MSL 2				X	X		
MSL 3	X		X				
MSL 4	X		X				
MSL 5	X	X				X	
MSL 6	X	X	X				
MSL 7			X			X	
MSL 8			X				
MSL 9							
MSL 10			X	X	X		

The two studies show some conceptual overlap. A structured comparison (Table 19.1) of the MSL dimensions and MLR challenges indicates that MSL is primarily discussed by the literature in the context of the orchestration of mobile learning experiences. This corresponds to the general notion of seamless learning as an instructional method. Surprisingly, the MSL dimensions could not be mapped to the organizational constraints and opportunities of mobile learning. This suggests that MSL is currently not studied at the organizational level. The comparison further indicates that the MSL dimension "knowledge synthesis" cannot be directly mapped to one of the distinct research challenges in the mobile learning domain. This comparison suggests that Wong and Looi's dimensions address mainly the educational design aspects of mobile seamless learning, while Börner et al. emphasize the overarching challenges of mobile educational solutions without explicitly considering educational and cognitive processes.

Given the conceptual differences of both categorization attempts, it is possible to analyze the nature of the seams for mobile learning in SDL that were identified by the ADL experts. As mobile SDL is considered to extend, existing ADL concepts such as analysis needs to take into account that the present SDL practice in security and defense organizations already targets seams for professional education and training. Therefore, any analysis has to consider the present ADL practice as a baseline for tailoring and categorizing future solutions.

With respect to the MSL dimensions, the barriers for mobile SDL highlight three aspects (Table 19.2): First is increasing the flexibility and continuity of learning across time and locations as an expansion of the baseline set by the current ADL practice. Secondly is bridging between formal education and training and authentic professional experiences in the real world. This relates to the SDL seam "bridging between theory and application" (SDL 1), which matches the MSL dimensions "Encompassing formal and informal learning" (MSL 1) and "Encompassing physical and digital worlds" (MSL 6). Third is linking mobile devices and solutions with the

Table 19.2 Mapping of mobile SDL seams to MSL dimensions

	ADL	SDL 1	SDL 2	SDL 3	SDL 4	SDL 5
MSL 1		++				
MSL 2	O					
MSL 3	++					
MSL 4	++					
MSL 5				O		
MSL 6		+				
MSL 7					++	O
MSL 8						O
MSL 9						O
MSL 10						

++ strong relation, + related, *O* loose relation

existing ADL infrastructure (SDL 4). This relates to the "combined use of multiple device types" (MSL 7) as it allows blending mobile learning with the existing ADL tools.

This analysis indicates that some seams for mobile SDL are only partly or even unrelated to an underpinning educational design. "Mobile data connectivity, device availability, and financial constraints" (SDL 3) relate only loosely to the dimension "ubiquitous knowledge access" (MSL 5) with respect to challenges related to the data connectivity and how this could facilitate better access to learning. The "integration with existing educational practices" relates only loosely to the MSL dimension's "combined use of multiple device types" (MSL 7) with regard to blending into the existing ADL practice; "seamless switching between multiple learning tasks" (MSL 8) and "knowledge synthesis" (MSL 9) partially address the influence of the professional complexity on SDL. The purely organizational seam related to security requirements and regulations (SDL 2) cannot be matched into the MSL dimensions due to their educational focus. Approaches that integrate multiple educational and learning activity models (MSL 10) are currently not a perceived challenge for SDL. This appears to be related to the limited availability of solutions that provide opportunities for integrating educational approaches.

Comparing the seams of mobile solutions in SDL with the MLR challenges shows (Table 19.3) that the present challenges for this application domain are strongly related to providing better and more flexible access to learning (MLR 1), utilizing the new opportunities of the mobile technologies for learning (MLR 6), and their relation to the organizational education and training practice (MLR 7). Other aspects such as contextualized learning (MLR 2) and the orchestration of the related processes (MLR 3) are presently minor relevance: with respect to that, the need for orchestrating learning experiences is already well understood from the past ADL experiences, but due to the limited number of available mobile tools and apps, the implications of the new technology for existing approaches are difficult to estimate. Consequently, the technical aspects are more important at the current stage of adopting mobile solutions for SDL.

Table 19.3 Mapping of mobile SDL seams to the MLR challenges

	ADL	SDL 1	SDL 2	SDL 3	SDL 4	SDL 5
MLR 1	++	++			++	
MLR 2		O				
MLR 3	+	O			O	+
MLR 4	O					
MLR 5						
MLR 6					++	
MLR 7			++	++	O	O

++ strong relation, + related, *O* loose relation

Approaches and Solutions

The development and uptake of MSL for supporting SDL is still in its infancy. The related research and development is scattered and weakly connected. Presently, the practice is dominated by bottom-up approaches that address several elements of mobile information needs of professionals in security and defense organizations. However, most approaches are primarily focusing on performance support and are disconnected from the organizations' education and training. This confirms the perceived barrier regarding the interoperability with existing infrastructure (SDL 4) and regarding the integration with the existing educational practice (SDL 5).

The only few mobile learning projects in the security and defense sector target the seams for mobile solutions in organizational education and training. The following sections analyze four selected projects regarding their approaches in relation to the dimensions and seams of MSL in SDL. The selected projects are implemented as demonstrators and feasibility studies in order to show the practical relevance, to identify further requirements, and to align the approaches to the organizational practice. Consequently, the projects do not address all dimensions and barriers of MSL in security and defense organizations. The analysis shows how the projects address the specific MSL dimensions and respond to the challenges and seams for mobile SDL.

Ubiquitous Knowledge Access and Interoperability with Existing Infrastructure

Beligan et al. (2012) developed a system for distributing SCORM-based learning material to mobile devices. This system allows learners to download the course material to their mobile devices for accessing it whenever they find time for learning. Alternative mobile interfaces of the SCORM runtime engine are at the center of this approach. Alternative interfaces provide optimized user interfaces for device

Fig. 19.2 Mobile ADL SCORM player screens (Based on Beligan et al. 2012)

platforms that enable learners to access the functions of the available infrastructure. In the case of mobile devices, these interfaces are designed for meeting the specific constraint of the small screen estate but share the same functions as the desktop-optimized interfaces of the existing infrastructure (Fig. 19.2).

The approach addresses the limitations of present SCORM platforms for distributing resources to security and defense professionals. The solution provides a solution for primarily text-based course modules that are widely available in security and defense organizations. This encompasses the integration of mobile devices with the existing ADL practice (SDL 5). Many of the SDL course modules that are available as SCORM packages define sequences of image-enriched text resources. While the mobile device is online and connected to the SCORM-runtime of the virtual learning environment, through this mobile learners can access their courses as if they were using a desktop or a laptop computer. This allows using mobile devices as an additional distribution channel for SCORM-compliant learning material. This addresses the need of security and defense organizations for the interoperability with existing infrastructures (SDL 4) and therefore improves the access to learning through mobile devices (MLR 1).

The authors highlight that learners in defense organizations often suffer from limited wireless data connectivity. Thus, their solution supports a special offline mode: learners can select courses for offline access. In this case, the solution converts the noninteractive resources of a SCORM package into an e-book and stores it on the learner's device. This feature increases the flexibility for accessing the learning material even in contexts with bad or no data connectivity both with respect to the time (MSL 3) and to the location of learning (MSL 4). However, the solution does not go beyond the educational scenarios that were already discussed in the ADL context.

Bridging Between Formal Learning and Practice

Hodges and Stead (2012) report on the MoLE project that provides a mobile application for learning and performance support for health care in defense organizations. The application provides learning units, field handbooks, and data collection forms conveniently on a mobile device. The objective of this solution addresses

Fig. 19.3 Mobile health-care training (Based on Hodges and Stead 2012)

the need for bridging education and training towards the professional practice. The solution focuses on the specific needs of health care for defense professionals including first aid and personal fitness. The core design objective of this solution is to provide a solution that allows professionals to switch between learning and application tasks (MSL 1) (Fig. 19.3).

In the learning mode, the MoLE app primarily provides multimedia learning material and tests. This material is used for the basic health-care training for US- and NATO-soldiers. The app includes all related standards and regulations as well as physical exercises in addition to the learning material. Each exercise has a text description, a schema of the movements, the performance requirements for the formal assessment, and (partially) a short video sequence. The exercises include a tracking mode, so the learners can track their performance and verify their fitness for the formal performance assessments. The app links digital resources with physical practices based on standardized training plans that link to the organizational performance requirements through this feature (MSL 6).

Through special mission tools, the app connects the formal learning resources with informal learning in missions. These tools provide operational guidelines and data collection forms that allow the professionals to collect and store relevant material conveniently on their device. The integration of mission and learning tools in a single app aims for satisfying the needs for bridging between theory learning and application of knowledge (SDL1). With this respect, the MoLE project primarily focuses on the challenges of accessing information in different contexts.

Collaboration or the integration with other learning activities without support of the solution is not envisioned by the project.

Related to the actual mobile learning solution, Hodges and Stead analyzed and compared the ethical regulations in military organizations in Northern America and Europe. Although these regulations primarily address personal integrity and security of military personnel in human subject research, they have implications for collecting and using data in mobile learning applications that focus on health-care education. Although such regulations are not necessarily applicable to other aspects of SDL, they provide guidelines for the sensible use of personal data and information in military contexts. The authors analyzed how the MoLE application considers the different national and international regulations for monitoring and responding student performance (SDL 3).

Embedding Anywhere-Anytime Learning into Educational Practices

Glahn (2012b) discusses a framework for embedding mobile exercises with organizational infrastructure using existing educational material. This solution is based on the Mobler Cards app (Fig. 19.4). The solution addresses the organizational demand for repurposing existing learning material for new technological solutions as the creation of learning material for a new kind of learning technology is perceived as a major barrier (SDL 3).

The solution uses existing learning resources that are typically used for assessments in order to support continuous practicing inspired by flash-card learning. The solution is based on a mobile application that is connected to the organizations' existing educational infrastructure. When using this application, the learners receive exercises in the form of small challenges, to which they have to respond. Based on their responses, they receive immediate feedback on their performance. These exercises are complete activities without external references or requirements and can be completed quickly. This enables learning in settings that are typically not suited for

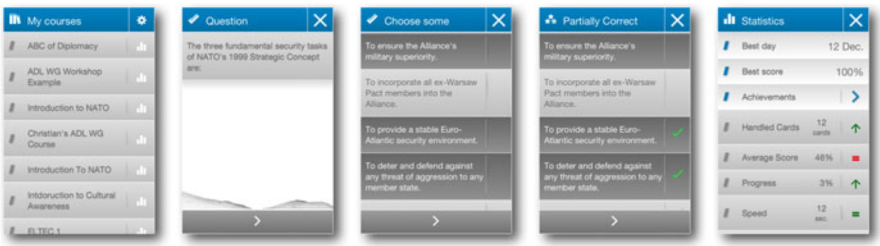

Fig. 19.4 Mobler Cards screen examples

conventional approaches. In addition to the immediate performance feedback, the solution allows the learners to analyze their performance also at a course level. This enables them to self-assess their performance.

Through the integration into the organizations' educational infrastructure, the solution inherits the orchestration logic of courses and learning opportunities (SDL 4). The organizational data protection and cryptographic requirements are considered by the solution by implementing the OAuth protocol. This demonstrates how third-party mobile applications could get connected to educational infrastructure without transferring personal credentials over potentially vulnerable data connections (SDL 2).

The integration with the existing educational infrastructure allows educational designers and instructors to embed mobile exercises into more complex learning scenarios and designs (SDL 5). The learning material used by the application is created, organized, and managed like any other content in the learning environment. As the mobile app responds to the orchestration rules defined by the learning environment (MLR 3), it implicitly enables interdependent blended learning scenarios that incorporate mobile and desktop devices (MSL 7).

The proposed approach is based on mobile interfaces for alternative learning activities. Different to alternative mobile interfaces, this approach presumes that learners have different needs in a mobile learning scenario than they have in the conventional web-based training context while pursuing a learning objective. Given the reduced size of the individual learning activities, the solution expands learning opportunities into times and locations that are otherwise unavailable for conventional learning approaches (MSL 3 and MSL 4). With this regard, the solution uses the learners' mobile devices to broaden the access to learning (MRL 1).

Orchestrating Social Learning for Bridging Between Theory and Application

Ternier et al. (2012) present the ARLearn framework for mobile-augmented simulations. The ARLearn framework uses mobile devices to support team learning by increasing the authenticity and the flexibility of the learning scenario. The framework allows arranging learning activities into complex and variable scenarios by anchoring activities to contexts (MLR 2, MLR 3). Personal mobile devices are used to augment the learning activities of a virtual scenario into personal or collaborative processes that take place in physical environment (MSL 6). This framework has been used for training small teams for crisis management in a hostage-taking scenario. The training is based on a basic script through which a mobile application guides the trainees. Interrupting seemingly random escalations add complexity and authenticity to the scenario and enrich the script (Fig. 19.5).

In the past, these training were conducted as moderated role-play scenarios. While these role-plays were practicing the basic script, the complexity of the setting made it very challenging for a moderator to coordinate events and escalations.

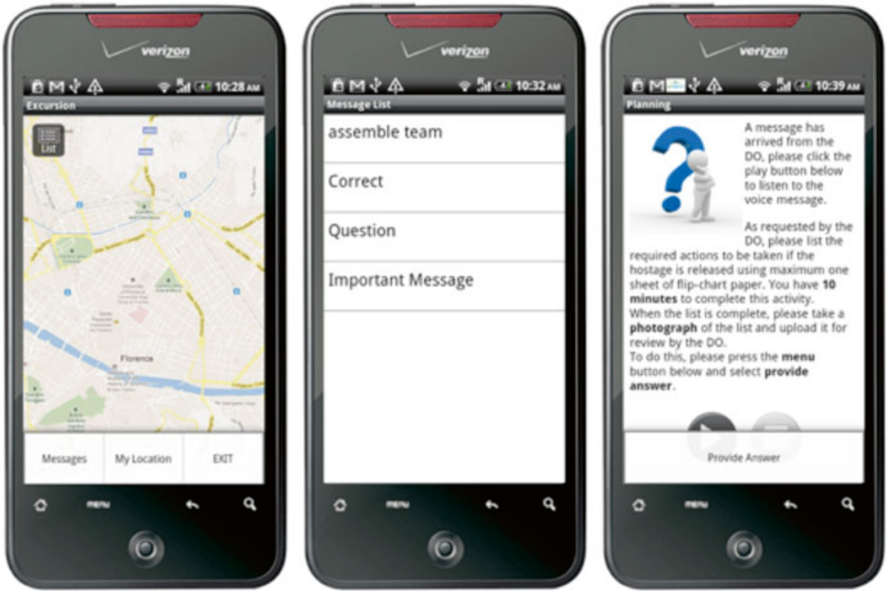

Fig. 19.5 ARLearn screens from the UNHCR hostage-taking training (Based on Ternier et al. 2012)

However, these "additional" events are essential for preparing the participants for a real emergency situation. With the ARLearn framework, moderators can extend their role-playing scripts through a mobile-augmented environment (SDL 5). Moderators can flexibly increase the complexity of the script by activating events or setting out new tasks and objectives depending on the performance of the participants. This allows personalizing the learning experiences based on the team performance (MSL 2). The mobile devices are used to inject activities and challenges into the setting via "phone calls," "e-mails," or "text messages," which creates more authentic experiences for linking the learning activities to the participants' professional environments (SDL 1).

The use of mobile devices further create opportunities for providing these role-playing activities for staff members in the field and thereby reduce the need of travelling to training facilities. This may influence the costs for such practice-oriented security training, indirectly.

Challenges for Future Research and Development

The analysis in this chapter shows that MSL in security and defense organizations is still in its infancy. However, the presented approaches already indicate the organizational complexity and the constraints that viable solutions have to consider.

The presented approaches indicate that most technology underpinning concepts of MSL and mobile learning contributed to the solution design. Although the four examples presented by this chapter can only spotlight, these examples show the bandwidth and potential of MSL in the security and defense domain.

The analysis of this chapter expands the notion of MSL based on a subject-matter expert inquiry. The inquiry identified five groups of seams that are relevant for introducing mobile technologies into the education and training practice of security and defense organizations:

– Bridging between theory and application
– Meeting security regulations as well as security and cryptographic requirements
– Mobile data connectivity, device availability, and financial constraints
– Interoperability of device features and interoperability with existing infrastructure
– Integration with existing educational practices

This perspective unveils new seams of using mobile technologies in the security and defense domain that were not or only partially considered in the prior analysis and discussion on MSL. Most notably is the emphasis of the organizational aspects of MSL with regard to regulations as well as to existing infrastructures and practices. These seams broaden the perspective of MSL beyond the realm of learning and education and show the relevance of organizational challenges and constraints of using mobile educational technologies in the security and defense sector.

This chapter analyzed which of the seams for mobile learning in security and defense learning were considered by the presented approaches. The alignment of the approaches to these seams (Table 19.4) indicates an emphasis on the educational aspects of linking theory education with practical training (SDL 1) and of integrating mobile learning solutions with existing practices (SDL 5). Furthermore, the selected projects indicate the relevance of embedding mobile learning solutions with the existing ADL infrastructure and concepts (ADL, SDL 4). This alignment also indicates that the present developments hardly consider the constraints of organizational regulations (SDL 2) and their practical consequences for accessing data and information on mobile devices (SDL 3). This focus indicates the early stage of MSL-related research and development in security and defense contexts.

With regard to the existing security relations and requirements (SDL 2), Hodges and Stead (2012) have analyzed organizational and national regulations and procedures for collecting, exchanging, and analyzing non-task-related information that is typically required for research and development projects. The primary scope of this analysis

Table 19.4 SDL challenges addressed by the presented approaches

	ADL	SDL 1	SDL 2	SDL 3	SDL 4	SDL 5
Beligan et al. (2012)	++				+	+
Hodges and Stead (2012)	+	++	O		O	+
Glahn (2012b)	+		O	O	++	++
Ternier et al. (2012)		++				++

++ core objective, + secondary objective, *O* partially addressed is the protection of personal data and integrity of military staff in international research programs. Glahn (2013) demonstrated the application of interoperability standards for acquiring and exchanging task-related data for connecting educational applications and services from different parties. Such approaches are essential contributions for bridging the seam of organizational data protection requirements while introducing new educational solutions and approaches. Both projects did not focus on these seams explicitly but considered them as subordinate aspects. Consequently, the overall contribution has to remain limited and the generalization of the findings to other projects and solutions has not been addressed.

A similar picture is present for mobile data connectivity, device availability, and financial constraints (SDL 3). Glahn (2013) considered this aspect only briefly by addressing limited or constrained data connectivity in the design of educational applications for security and defense audiences. The present research does not address the requirements and constraints for additional infrastructure such as secure wireless networking or mobile device procurement. Although subject matter experts perceive these aspects as a major seam for new educational technologies in security and defense organizations, they are not specific for technological support of military education. While research on mobile technologies for education and training can contribute to developing a better understanding of mobile security and data protection requirements, these activities have to be aligned with other mobile systems and frameworks that are part of the tactical and strategic operations in security and defense organizations.

With the increasing maturity of MSL solutions for applications in the security and defense sector, it becomes more important also to respond to the currently underrepresented seams for MSL at the organizational level. In the process, research will have to address these underrepresented themes more prominently and to propose practical and interoperable solutions to meet the specific requirements.

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Chapter 20
Mindergie: A Pervasive Learning Game for Pro-environmental Behaviour at the Workplace

Marco Kalz, Dirk Börner, Stefaan Ternier, and Marcus Specht

Abstract This chapter reports about a pervasive learning game to increase the environmental awareness and pro-environmental behaviour at the workplace. Based on a discussion of the theoretical background and related work, we introduce the game design and game elements. Results of a formative evaluation study are presented and discussed. Results show that incentive mechanisms are less important than challenging game components that involve employees in proposing solutions for energy conservation at the workplace. Conclusions are drawn for future games and energy conservation activities at the workplace.

Introduction

Several studies have shown the effect of human energy consumption on pollution and climate change (IPCC 2007; United Nations Environment Programme 2012). While in the home context monetary incentives are one of the main motivational aids to save energy, these incentives are not present at the workplace. In a recent study we have conducted we have found that only 25 % of employees in an academic organisation are concerned about the financial consequences of their individual consumption for the organisation (Börner et al. 2012a). Therefore, other initiatives are needed to increase pro-environmental awareness and behaviour change at the workplace.

In general, there are only a few studies that have focused on energy conservation at the workplace. A study by Siero et al. (1996) showed that the offering of information and learning opportunities about pro-environmental behaviour has the potential to change the attitude and behaviour of employees. A recent study by Lo et al. (2012) revealed that the main differences between the home and work context are that

M. Kalz (✉) • D. Börner • S. Ternier
Welten Institute, Open University of the Netherlands, Heerlen, The Netherlands
e-mail: marco.kalz@ou.nl

M. Specht
Welten Institute, Open Universiteit of the Netherlands, Heerlen, The Netherlands

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the costs of energy consumption are not monitored nor paid by the employee and that the organisation's structure, size, goals, etc. have an influence on individual behaviour. Furthermore, the authors stressed the importance to understand the psychosocial determinants of pro-environmental behaviour at the workplace, which differs from the domestic context. Earlier Kollmuss and Agyeman presented a model of pro-environmental behaviour based on a synthesis of literature that integrates internal factors such as personality traits or environmental consciousness and external factors such as infrastructure or political context (Kollmuss and Agyeman 2012). Additionally, they investigated and incorporated possible barriers to pro-environmental behaviour. These barriers are attributed to be responsible for the gap between attitude and action, also referred to as engagement gap. Among others the identified barriers were lack of environmental consciousness and knowledge, negative or insufficient feedback about behaviour, as well as missing internal and external incentives.

The lack of environmental consciousness, incentives, and feedback was the main motivation behind our study. Our secondary goal was to contribute research that helps to decrease the research gap formulated by Foster et al. (2012). The authors identified a "research knowledge gap present in understanding the end-users of energy in the workplace and, therefore, the design of appropriate and achievable workplace energy interventions, particularly those that encompass novel ways of encouraging people to adopt positive energy usage behaviour whilst at work." In this chapter, we report about a novel workplace energy intervention in form of a serious learning game called "Mindergie" implemented in a Dutch academic institution.

The chapter is organised as follows. In the next section we discuss related work, especially related game designs focusing on environmental education. Then we present the context and methodology of our research. The game design and game components are introduced. Results of the formative evaluation study are presented and discussed. Last but not least conclusions and implications for future work are drawn.

Related Work

Games and gamification are emerging topics that gain interest within higher education (Johnson et al. 2013). Games are used successfully as independent tools for training and learning in suitable application domains. Gamification describes the process to apply game elements and game design techniques in nongame contexts (Werbach and Hunter 2012). While playing games in general is highly motivational, gamification proves to be especially effective to close or overcome engagement gaps.

There is a large amount of games available for environmental education. Reckien and Eisenack (2013) have conducted a review about 52 board and screen games about the topic of climate change. Most of the reviewed games are role-play and management games that combine a global and local level of information. One of these recently developed games is presented by Fennewald and Kievit-Kylar (2013). In their common pool resource game they focus on increasing awareness of climate change and use of resources as a social dilemma. Eisenack (2013) reports about a board game for climate change education that enables players to see the climate change problem from different perspectives and triggers self-reflection and generalisation. Lee et al. (2013) have developed with GREENIFY an action-based game for environmental education that allows knowledge acquisition in authentic local and social contexts through a desktop-based solution.

Our motivation was to design a game in which learners can collect experiences and reflect in an authentic environment, but our goal was to not focus on the desktop as game framing but to take the office/campus environment as a whole as the gaming and learning environment. A similar approach has been implemented by Bång et al. (2009) in the form of a pervasive game for the household context. Montola (2005) defines pervasive games as games that have “one or more salient features that expand the contractual magic circle of play socially, spatially or temporally”. With Mindergie we have developed a pervasive game that is played in the authentic context of the work environment of employees with the focus to evaluate the potential of different game-design components on environmental knowledge, consciousness, and last but not least energy consumption behaviour of employees.

Method and Context

Our research is based on the design-based research methodology (Cobb et al. 2003). Design-based research addresses complex problems in authentic environments, integrates design principles with technological affordances, and conducts reflective inquiry with the target to refine learning environments and to identify new and emerging design principles. In contrast to predictive research that has the goal to specific and confirm or reject of new hypotheses, design-based research is targeting in the constant refinement of problems, solutions, methods, and design principles (Reeves 2006). According to the design-based research collective (Design-Based Research Collective 2003), the goals of developing theories and designing learning environments are intertwined and these activities constantly inform each other. Another goal of design-based research interventions is to communicate relevant implications to practitioners and other educational designers. In this sense, we see our contribution as an input to other practitioners, institutions, and educational designers who want to increase the environmental consciousness and foster conservation at the workplace. This project is embedded into a series of interventions that have been conducted to increase environmental awareness of employees. In earlier studies we have focused on using ambient displays for the increase of awareness about energy consumption at the workplace (Design-Based Research Collective 2003; Börner et al. 2013a) and the use of a sensor network to measure energy consumption on a personal level to provide feedback (Börner et al. 2012a). A full overview about the connection between these interventions is given in a related publication (Börner et al. 2012b). In this study, we had the goal to go beyond increasing awareness and providing personalised information, and we focused instead on the potential of a pervasive game to increase knowledge, pro-environmental consciousness, and last but not least change consumption behaviour.

The context of the research stems from a long-term national agreement on energy efficiency that public institutions have with governmental agencies. In this agreement the Open University of the Netherlands agreed on reducing the energy consumption by 2 % each year until 2020 and to raise awareness on this topic among employees. While the awareness-raising was limited mostly to some stickers and posters, we saw an opportunity to use mobile, pervasive, and ambient technology to reach this goal.

Our research questions for the study have been the following.

- Which aspects of a pervasive game have the most potential for improving energy consumption behaviour at the workplace?
- Which aspects of a pervasive game have the most potential for improving environmental consciousness?
- Do rewards in the form of digital badges and prizes have a positive impact on consumption behaviour and environmental consciousness?

To answer these questions, we have integrated and extended different technologies for the study. Participants have been recruited via an intranet news item of the organisation. The game was played from November until December 2012 for 4 consecutive weeks. The only requirement for participation was to have an Android smartphone or tablet available as well as to own a Google account. A limited amount of Android devices was available to borrow.

After registration the participants were invited to participate for the next 4 weeks in the weekly game rounds. The first week started with an introduction to the game and the technologies used to play it. Participation was voluntary; weekly prices were rewarded in the form of vouchers.

After the Mindergie game a questionnaire has been sent to participants via email. This questionnaire consisted of 21 items which were a combination of multiple-choice items, items with a 7-point Likert scale ranging from 1 (not at all) to 7 (completely), or open questions. The questionnaire focused on motivation of participants, overall satisfaction with the game, the potential of game components for changing the environmental awareness and behaviour change, and the granularity and amount of information presented during the game.

Technologies

The design of the pervasive game has been done with the ARLearn platform (Börner et al. 2013b). ARLearn is a platform for mobile learning games. The platform consists of an authoring interface that enables game designers to bind a number of content items and task structures to locations and to use game logic and dependencies to initiate further tasks and activities. The platform has been recently used for several similar pilot studies in the cultural heritage domain, the training of

UNHCR employees for hostage-taking incidents in international organisations (Ternier et al. 2012), and resuscitation training for first responders (Gonsalves et al. 2012; Kalz et al. 2013). The following motivation guided the decision to use the ARLearn platform to realise the game-based learning intervention:

– The ARLearn platform is multi-user enabled.
– The ARLearn platform is location aware, which allows for realistic gameplay settings.
– Commonly used smartphones can be used to play ARLearn games, which simplify game distribution.
– The event-based game model of ARLearn allows to design realistic game processes, which simulate mission critical real-life situations and conditions.
– The game design should be reusable so that the game can be easily adapted to other locations and contexts.

Media items (including multiple-choice questions, video objects, and narrative items) are a central concept in ARLearn. They can be positioned on a map or made available depending on the game logic. A video can thus be bound to a coordinate, it can appear at a certain moment as a message in the player's inbox, or it can appear or disappear based on actions taken in the game. Within a game, an author defines items, dependencies between items, game score rules, and progress rules. A run defines users grouped in teams. While playing, users generate actions (e.g. "read message", "answered question", "scan QR code") and responses. This output is also managed within the realm of a run. Specialisations of media items allow to ask questions (multiple choice) or to include multimedia (audio and video objects). Actions can lead (through dependencies) to new available items, increased scores, or increased game progress. Items have a simple life cycle with three states: Initially, an item can be visible or invisible (initial state). Invisible items can become visible (active state). When the item is no longer needed, it can become invisible again (used state). Items can define dependsOn and disappearsOn conditions for the state transitions. A simple dependency mechanism is put in place to support these conditions:

– Action-based dependencies are triggered by specified actions.
– Time-based dependencies bind time offsets to other dependencies.
– Boolean dependencies allow combining other dependencies logically.

Besides ARLearn we have used a signage solution to display content on existing displays on the campus and recruit participants for the game (see Fig. 20.1).

For the incentive component, we have integrated and used the Mozilla Open Badge Infrastructure (Schmitz et al. 2013). The Mozilla Open Badge Infrastructure (OBI) has been developed to recognise learning activities in a non-formal context. Several institutions in the USA like the NASA, the Walt Disney Company, or Intel have piloted badges as a new approach for rewarding learning and competence development of employees.

A central element for an earner of badges is the "backpack" in which badges are stored. A backpack is solely controlled by its user, and after earning a badge,

Fig. 20.1 Signage system in use for content distribution

the user can decide whether to accept or deny a badge and to make it public or not. So the infrastructure allows users to earn, collect, and share badges. The infrastructure consists of a management interface (i.e., user's badge backpack) as well as a specification to issue and display badges. The badges are then published automatically or uploaded manually to the user's badge backpack where they can be managed and made available to show on other websites via the Displayer API. From the backpack of the badge earner, these can be easily shared to social networks like Twitter, Facebook, or Google+.

Badges have a long history as incentive and social mechanism for sharing the social status or activities of individuals or groups (Mozilla Foundation 2013). A recent study by Abramovich, Schunn, and Higashi (Halavais 2012) has concluded that the benefit of using badges in education depends on the badge type, motivational background, and usage context. As an alternative incentive, we have used weekly prices to combine digital and nondigital incentives.

The full architecture for the Mindergie game is depicted in Fig. 20.2. At the left side, two cloud-based components are presented:

- The Open Badge Infrastructure manages badges. This infrastructure enables integration with third-party systems through an API to submit badges and an API to display badges.
- The ARLearn game engine manages the game. Client devices, such as the ARLearn Android app, communicate with the game engine via a web services API.

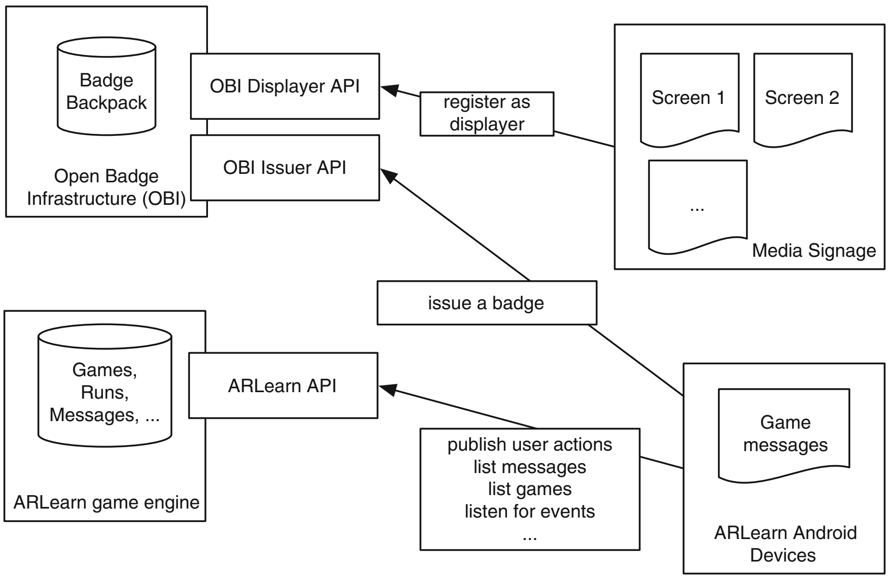

Fig. 20.2 Architecture for the Mindergie game

At the left side of this diagram, components are displayed that consume these services.

- The ARLearn Android app synchronises game progress with the game engine. A "Mozilla Open Badge" is a special kind of ARLearn message. As this message is made visible, the user can decide to collect the badge. The app awards the badge by making a call to the OBI issuer API that adds the badge to a user's backpack.
- The media signage component registers with the OBI Displayer API to display badges that were awarded to Mindergie users.

With this infrastructure, we have designed the Mindergie game. The game design and the formative evaluation study are introduced next.

Game Structure and Gameplay

Game Components

Table 20.1 shows the game components that have been implemented to address problems identified in earlier research.

The game design was constructed from the following game elements: information, action, challenge, activity, quiz, and badge.

Table 20.1 Identified problem areas and game elements

Environmental consciousness	Lack of incentives	Lack of feedback
Information/knowledge components	Digital badges	Knowledge tests
Energy statistics	Rewards	Challenges

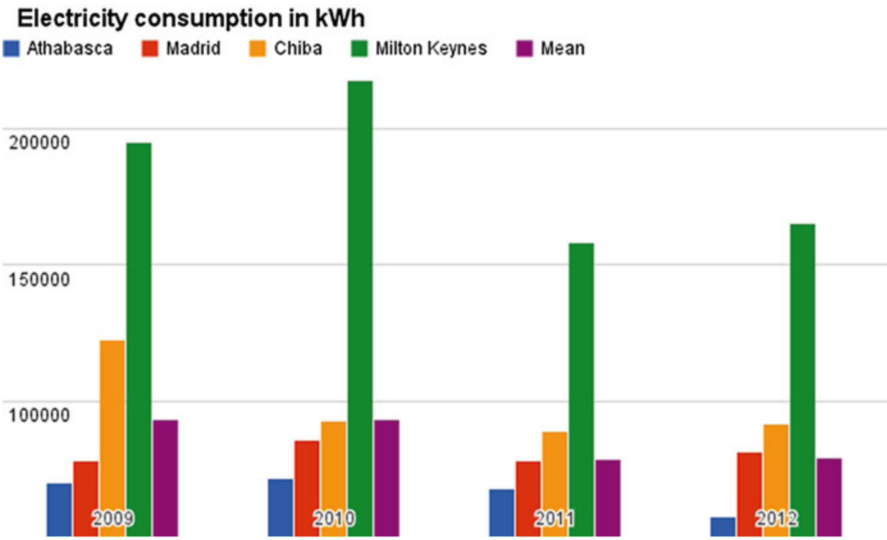

Fig. 20.3 Mindergie statistics element example

The *information element (knowledge component)* provided the users with all the important knowledge, e.g. about the game, energy consumption details, conservation possibilities, saving potentials, etc. The knowledge components are organised according to the topic of the week and participants are expected to know mean energy consumption for households and individuals and activities that have the biggest saving potential. As a variation of the knowledge element in a text format, videos provided the users with simple tips on how to conserve energy. Thereby we made use of available topic-related material. As alternative to the information elements, dedicated energy statistics have been provided to the players. An example is shown in Fig. 20.3.

These statistics have been manually collected from the energy control system of the organisation and have then been transferred to simple comparison figures. Examples of the statistics element include electricity consumption (as shown above), the comparison between workday consumption and weekend consumption per building, and heating patterns. Mostly, these statistic items have been combined with open questions in which the player had to record an audio or video interpretation of the statistic shown.

Action elements were used to get users active and let them do something, e.g. find something out, save some energy, or propose a solution. While the activity element was focusing on the collection and registration of concrete energy-saving activities of the participants, the action element triggered activities on the campus. To perform actions they had to leave their workplace and reach different places on the campus, e.g. the game flags we deployed in the centre of the campus. Most of the time actions combined information clues and assignments at the same time. A sample action looked like this: “Athabasca is a rather small building on our campus, which consumed in total 1,154 kWh electricity last week and 200 kWh on average per working day. With 256 kWh the highest electricity consumption in Athabasca was on Thursday. Last weekend Athabasca consumed 152 kWh without anyone in the office. Now look for the small QR code attached to the ‘Chiba’ flag pole and scan it”.

The *challenges* item invited the user to elaborate and reflect by sharing personal opinion and experiences. These items dealt with the users and their personal account of the workplace context and different media were used for this. A sample challenge looked like this: “Visit the website and enter the data about your ecological footprint. Record a video in which you reflect about your ecological footprint and propose future activities to make this footprint smaller”.

The *activity elements* were used to register the conservation activities of participants. The idea was to get an impression of their habits, so they were asked to be honest and only register activities they had really done. Following that codex, they were allowed to register as many activities as they liked from a list that was adapted weekly to the theme of the week, e.g.

- Switch off appliances instead of leaving them on standby.
- Disconnect power supply units when not in use.
- Use multiple socket power strips that can be turned off.
- Switch off lighting when leaving a room.
- Use appliance built-in energy-saving options.

For the *incentive component,* we have combined digital badges with weekly prizes. In the preparation phase of the game, a set of badges for each week has been designed. Examples of these digital badges for the Mindergie game are shown in Fig. 20.4.

A set of badges has been designed for the project. In total four types of badges were used, one for the general gameplay and one for each category. The different types of badges are distinguished by form and colour. Each badge is characterised by a unique symbol illustrating its meaning. Furthermore, each badge can have three different states or levels reaching from bronze over silver to gold. As alternative reward to the digital badges, we have provided weekly small prizes to participants of the game:

– 1x book voucher for the employee who collected the most information
– 1x activity voucher for the most active employee who performed all the actions
– 1x electronic media voucher for the employee who mastered all the challenges

Fig. 20.4 Mindergie badges

If there was more than one employee qualified for the prize, then the winner was chosen at random. Furthermore, there was an overall prize for the best player (aka. the greenest employee), announced and awarded after the game.

The *quiz element* was mainly used to assess the knowledge acquired during the game, e.g. by reading all available information or watching the information videos. Usually, this element became available only after accessing all necessary elements. The outcome was taken as basis to issue badges. Finally, when users demonstrated a skill or achievement, they were usually rewarded with a badge. The respective element then became available and could be used to store the earned badge in the personal backpack.

Game Design

The Mindergie game has been designed in four individual sub-games that had all different goals. While the first week was introducing the game and the topic, the second week focused on the topic of "electricity", the third week on "heating", and the last week on the "individual energy footprint" of employees. We followed in the game design general instructional design principles to first build a shared knowledge base and activate prior knowledge of participants via knowledge/information components. Based on this shared knowledge base, we provided the participants with contextualised information and real problems of the campus environment for which solutions could be proposed by participants. This should have made the game on the one hand relevant for their direct context and on the other hand authentic and personal.

The game description for the first week's "introduction" run is illustrated in Fig. 20.5. The game starts with a welcome message that briefly explains the game and the goals and tasks of the week. Arrows indicate dependencies between the single items. After the welcome message has been read the message appears in the list.

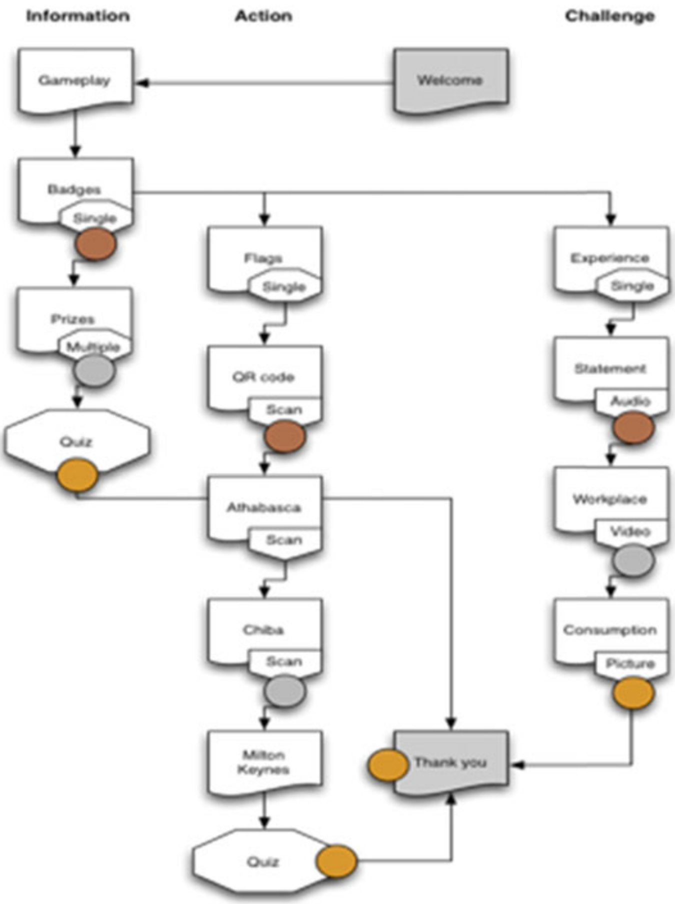

Fig. 20.5 Mindergie week 1: introduction

There are three different item categories in the game, namely, information, action, and challenge. Within these categories the simple text items are represented by the document symbol. Octagons represent single or multiple-choice question items, while pentagons pointing downward represent open-answer items. Scanning a QR-code, recording an audio statement, taking a picture, or capturing a video can answer the open-answer items. Finally each circle symbol represents a badge that can be achieved throughout the game.

The game logic for the other weeks was mainly enhanced by combining all game items and focus on one of the three topics. The game description for the second week on "electricity consumption" is illustrated in Fig. 20.6. A set of information items and videos about effects of electricity consumption and saving options has been combined with challenges and actions. The completion of tracks in the game

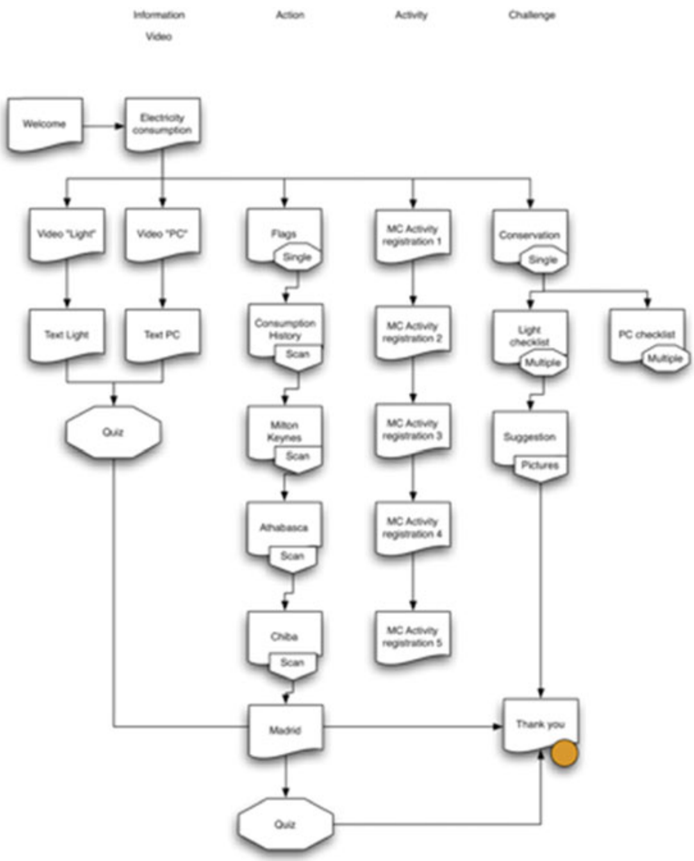

Fig. 20.6 Mindergie week 2: electricity consumption

included a quiz item and the delivery of badges. This design has been repeated from week 2 to week 4 with different topics.

The game components have been integrated in four different game runs of the ARLearn platform. Each week players received a message via mail that a new game is available to them.

Gameplay

Each week started with an introduction into the topic of the week. After opening the ARLearn app and the Mindergie game, participants received this introduction message via a notification on their phones. After accessing the welcome item,

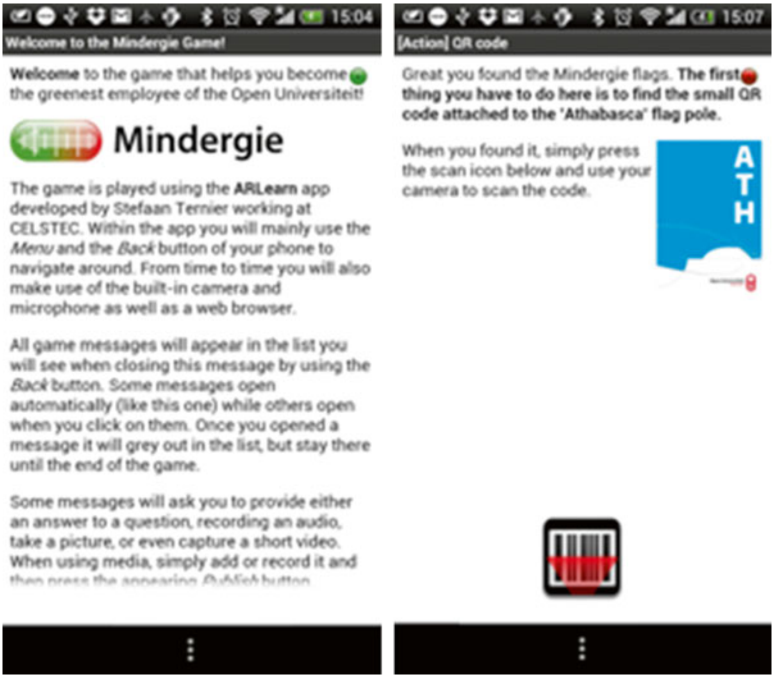

Fig. 20.7 ARLearn mobile client

several knowledge/information items have been made available. These knowledge items all depended on each other so that players have followed here a structured approach to build a shared knowledge base about the specific topic of the week. Challenge items asked participants to scan a barcode at a specific location on the campus. This scan triggered again further information items like overview statistics with a reflection task or presented players with a concrete task. In the meantime, players could register energy-saving activities whenever they wanted. At the end of the week, a quiz was made accessible depending on completion of items during the week. Depending on full completion of activities, a badge has been issued. In addition, we have assessed the input by participants via a portfolio page for each game and have decided which player would win one of the weekly prices.

Using the ARLearn mobile client (see Fig. 20.7), media items – the main ARLearn elements – appear as messages. Some messages open automatically while others open when users click on them. Messages can comprise different media, e.g. text, audio, or video. Some messages also ask users to provide either an answer to a question, recording an audio, take a picture, or even capture a short video.

ARLearn uses a simple rule-based approach that allows defining actions, time, or location-dependencies for all available items. With dependencies it is possible to implement game structures. This means, e.g. that when a game starts, only the first

Fig. 20.8 Earned badge shared via Twitter

item is visible to a user. Next after the first item has been read, the second item becomes visible, etc. Secondly, dependencies enable giving users feedback based on answers that were given. For instance, if a multiple-choice question defines three answers, dependencies allow selecting which item should appear when a user provided a specific answer.

Each item type was noted [in brackets] in front of its title. From time to time users were asked to answer questions, either as part of an item or in the course of quizzes. Usually when answering questions, read information, perform actions, or master challenges new items appeared. Users did not have to do everything at once. They could return at any moment and proceed with the game.

During the game users could earn badges that demonstrate a skill, achievement, or quality. If users successfully answered questions, read information, performed actions, or mastered challenges, they received a badge for that. As described we made use of Mozilla's Open Badge Infrastructure for the issuing of badges. The Mozilla infrastructure does not allow systems to issue badges without a user's consent. So whenever users received a badge, a browser window opened, they had to sign in with their Mozilla Persona id, and then accept the badge. When they did that, the badge was stored in their badge backpack, which also allowed social sharing (see Fig. 20.8).

Since we followed an action-oriented approach, it was important to not stress the "knowledge transfer" items too much but to also include participants in improving the local work environment in terms of energy conservation.

For this purpose, we have integrated a special kind of action element in which the task was to make suggestions for a specific energy conservation problem at the campus and document this via a media item (photo or video). Figure 20.9 shows an action item in which players had the task to identify rooms in which the installation of a movement sensor for switching the lights on and off would make sense.

During the game we had installed an email helpdesk to support players in overcoming difficulties during the game.

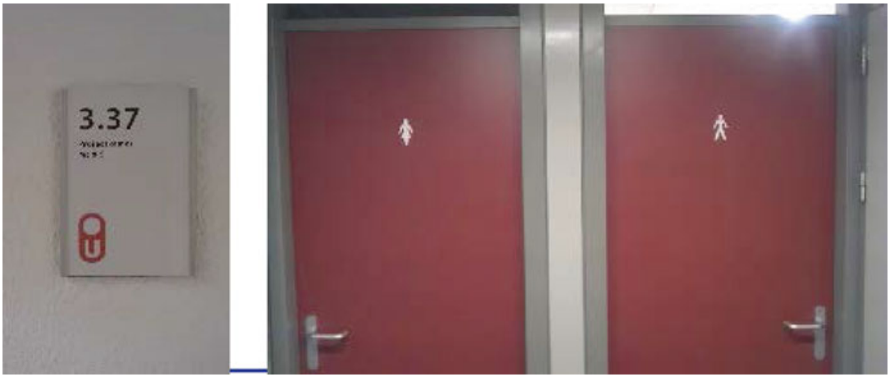

Fig. 20.9 Action item suggestions

Data Analysis and Results

From the 15 participants, at the end of the game 12 participants completed the questionnaire and thus provided qualitative feedback on the game. Table 20.2 presents an overview about questions asked and data collected.

As expected the results show that participants are highly concerned about the amount of energy they are using at the workplace ($M = 5.42$), especially regarding the environmental costs, such as higher environmental pollution. They are also highly concerned with what they can do personally to reduce their energy consumption at the workplace ($M = 5.75$) and performed the suggested energy-saving tips. When asked why they are not doing more to reduce their energy consumption at their workplace, the participants asked for more information and detailed feedback on their personal consumption. The majority of participants is highly motivated to take more actions to further reduce their energy consumption at the workplace ($M = 5.08$).

Overall, participants were satisfied with the game ($M = 4.25$). The amount of information has been evaluated positively ($M = 4.67$). The granularity of the information presented during the game shows even a higher satisfaction level. ($M = 4.83$). The gamification of the Mindergie game has also been evaluated positively ($M = 4.92$). The comparison of the different game rounds has revealed that the second round has been evaluated as the best designed one. For the later rounds, participants criticised the similarity of structure.

When asked to evaluate the game, the participants stated that the gamification was appealing ($M = 4.92$). Overall the participants liked "active" game elements, such as action, challenge, and activity most. The "informational" elements, such as information and video, were less popular, while badges ranged in between the two. Regarding the expected behaviour change, participants stated that the game in general changed their energy consumption behaviour ($M = 4.25$), while the information and the activity elements were assigned with the highest potential to do so.

Table 20.2 Questions and question types

Question	Type
Are you concerned about the amount of energy you are using at your workplace?	Likert scale
What is likely to make you most concerned about the amount of energy you are using at your workplace?	Multiple choice
Are you concerned with what you can do personally to reduce the energy consumption at the OU?	Likert scale
Are you doing any of the following activities to reduce your energy consumption at your workplace?	Multiple choice
Why are you not doing more to reduce your energy consumption at your workplace?	Multiple choice
Are you planning to take more individual actions to reduce your energy consumption at your workplace?	Multiple choice
To which degree can you estimate how much energy (electricity) you use individually at your workplace?	Likert scale
To which degree can you estimate how much energy (gas) you use individually at your workplace?	Likert scale
Did you actively participate in the game?	Likert scale
Was the gamification appealing to you?	Likert scale
Which game round(s) did you like most?	Multiple choice
Which game element(s) did you like most?	Multiple choice
Did the game change your energy consumption behaviour?	Likert scale
Which game elements had the most potential to change your energy consumption behaviour?	Multiple choice
Did the game enhance your environmental consciousness?	Likert scale
Which game elements had the most potential to enhance your environmental consciousness?	Multiple choice
Was the information presented useful and relevant for you?	Likert scale
Were you satisfied with the amount of information presented?	Likert scale
Were you satisfied with the granularity of the information presented?	Likert scale
How satisfied were you with the game?	Likert scale
Please provide some feedback about the game?	Open question

Regarding the environmental consciousness, participants stated that the game enhanced their environmental consciousness ($M=4.67$). In this regard, the information and video elements were assigned with the highest potential to do so. Participants stated that the "active" game elements had a slighter higher potential to change energy consumption behaviour compared to the "informational" elements and vice versa for enhancing the environmental consciousness. The badge and prizes elements were in general assigned with the lowest potential, while the potential to change the consumption behaviour was higher compared to the potential to enhance environmental consciousness. All results depicting the potentials are compiled in Table 20.3.

Table 20.3 Game element potentials

Game element	Energy consumption behaviour (Mean)	Environmental consciousness (Mean)
Information	5.50	5.67
Video	4.42	4.83
Action	4.33	4.08
Challenge	4.33	4.17
Activity	4.58	4.42
Badge	3.92	3.42
Prizes	3.17	2.83

In addition to the rating of items on a Likert scale, participants have been asked to provide qualitative feedback about the game, the game components, and the technology. Here is a selection of these open comments.

– + it was fun + I learned a lot + easy accessible + good use of a mobile device, like the code scanning, making pictures and videos […]
– I really enjoyed the game, nice way of becoming aware of energy consumption […]
– Fun and exciting way to learn more about reducing your ecological footprint
– Game was overall quite fun […] In any case, the main thing is that it was fun and well structured and organized. Without the prizes it would have been as fun as with for me.

In conjunction with some negative points, participants also came up with ideas and suggestions on how to improve the game.

– […] more players on the campus would be nice, probably also team play would be cool
– […] would be even better to be more intrusive about the energy consumption, more live analytics. It would be really nice to get feedback about typical activities like energy costs for making one printout, make a copy, take a coffee, etc. so live tracking of energy consumption to compare the single activities and devices. That could make a real change as I would try to reduce the top ten energy consumption devices/actions in the office.
– The game was not what I expected it to be. I expected to do more with the app, more a game like app […]
– Found it hard to combine game activities in my daily work […]
– […] After 3 weeks the structure became repetitive. Also, I expected some more innovation (e.g. in the way the QR codes were used or something) […]

These comments show that the type of game has been appreciated by most participants. Since there was no extra time available for the game, some participants reported that they could not continuously participate in activities of the game. This is of course a challenge for gamification, especially when this is applied in a business or work context. Thus, an energy conservation game that is played in the work context must be designed in a way that the individual game activities can be played and continued at any time to allow participants also to use small time slots for gaming activities.

Discussion and Conclusions

Results of the study show that a pervasive game is a promising approach to involve employees actively in the energy conservation of an organisation. Interestingly, reward mechanisms in the form of badges and prizes had the lowest impact on the behaviour and environmental consciousness of participants. Although missing reward mechanisms have been formulated in the literature as one of the barriers for energy conservation at the workplace, the reward mechanisms used did not sufficiently address this problem.

This might have to do with the fact that digital badges are primarily designed for cross-organisation recognition of prior learning and participants of a higher education institution might not see a need for badges that refer to pro-environmental behaviour rather than expertise for a specific topic. In this sense it is also questionable if our usage of badges has produced competition of participants. Abramovich et al. (2013) report that the effect of digital badges in an educational context depends on the prior knowledge and type of badges used. While we have primarily used participation badges, it might have been useful to combine these with skill badges. Another complication of the rewards has been described by Kohn as the "risk of rewards" (Kohn 1994). According to the author behaviour modification programs are problematic since mostly the rewarded behaviour stops when the reward is taken away. Therefore, the author recommends the investment in what he calls "good values" rather than rewards.

All game elements that have contributed to knowledge building or that have involved participants in problem solving or the development of own ideas (activity, action, challenge) have more influence on pro-environmental consciousness and pro-environmental behaviour according to participants. In future scenarios and designs, we should therefore invest more into the exploration of these game components.

The qualitative feedback has further enriched the results with proposals by participants on how to improve the involvement of participants and the scaling of the intervention. While the activating game components have been appreciated by the participants, they also called for a change in the game design and no repetition of game logic and activities. It has been suggested that team play could address this problem. Another suggestion was more personalised feedback about individual energy consumption. We had planned this in one of the first designs, but we did not realise this due to a lack of sensoring devices.

To provide employees with personalised energy consumption feedback as requested in the results, a pervasive sensor network would be needed to be able to implement ongoing feedback loops (Goetz 2011) in which the gap between activities of employees and effects on consumption of the organisation could be made visible without delay leading to well-known social trap phenomena (Cross and Guyer 1980). For this purpose the organisational support of the whole organisation and its management is needed.

The study has several limitations. Due to the decision to use technology which was at the time being only available on the Android platform, we could not attract a sufficient amount of participants. For a more summative evaluation study, the technological platform needs to be more flexible to attract a larger number of participants. In addition, due to the short duration of the study, we cannot make any claims about behaviour change that has actually taken place.

Another limitation of the study might be a potential selection or participation bias of participants. The low value of the rewards and the qualitative feedback suggest that the intrinsic motivation be active for energy conservation at the workplace was already present for most participants. A future study would need to attract not only a larger group but also a more balanced group of participants. To evaluate long-term effects and the increase of pro-environmental behaviour of employees on a larger scale, a longitudinal study would be needed that was beyond the timeline of this project.

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Chapter 21
Seamless Learning from Proof-of-Concept to Implementation and Scaling-Up: A Focus on Curriculum Design

Chee-Kit Looi and Peter Seow

Abstract Many educational research projects focused on designing curricular innovation or establishing design principles for guiding curriculum design and teacher facilitation that work well within specific contexts. When the curriculum is scaled up from one class to all classes in one grade level in a school, the design principles need to be fine-tuned iteratively to work well in more diversified contexts through a process of design-based implementation research. This is one main consideration in the trajectory of moving a curricular innovation from the research phase to implementation and scaling phases. This chapter addresses the broad challenge of understanding how more successful research innovations can proliferate to more usages, adoption and adaptation across levels of the education system in the context of seamless learning. This is done in the context of scaling up a seamless learning curricular innovation in a Singapore school. We focus on the articulation of principles for designing the curricular activities that adhere to the spirit of seamless learning and that have the potential for sustainable and scalable implementation by teachers.

Introduction

Seamless learning refers to the synergistic integration of the learning experiences across various dimensions such as formal and informal learning contexts, individual and social learning and physical world and cyberspace (Chan et al. 2006). The basic premise of seamless learning is that it is not feasible nor productive to equip learners with all the knowledge and skills they need based on episodic learning time frame, location or scenario (Chen et al. 2010), typified by how learning takes place in formal education. Mobile technology has the potential to mediate seamless learning (Looi et al. 2010). While formal learning is based on fixed curricula enacted in

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C.-K. Looi (✉) • P. Seow
National Institute of Education, Nanyang Technological University, Singapore, Singapore
e-mail: cheekit.looi@nie.edu.sg

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classroom environments, informal learning happens when learners are participating in intentional or unintentional experiences outside school settings. The two forms of learning should not be seen as dichotomous and as conflicting situations (Sharples 2006). Instead, by utilizing the affordances of mobile technology, seamless learning can bridge the gap between formal and informal learning and encourage students to learn in naturalistic settings.

There are many facets to seamless learning research such as theorizing seamless learning, designing technologies, developing or refining research methodologies, developing design principles, evaluating specific seamless learning designs, transforming them into routine practices for learners and teachers and scaling up seamless learning curricula. This chapter is a contribution toward the last two facets through the description of the research experiences, findings and reflections from the efforts of creating and up-scaling a seamless learning curriculum in a primary school. It first delineates the principles of a seamless learning model which was used, refined and iterated to transform a traditional primary science curriculum into a mobile device-enabled seamless learning curricular innovation. It then discusses the issues of implementation and scaling of such a successful seamless learning innovation from one class to all classes in a grade level in a school.

A Curricular Innovation Informed by the Seamless Learning Notion

There are several aspects and approaches to designing for seamless learning. Several researchers have looked at the design of a specific curricular activity lasting a few days to a few weeks. In designing for sustainability, we want to work at the level of whole curriculum which spans the minimum duration of an academic year. Two different approaches to designing for seamless learning can be contrasted in relation to the starting point of the design: first foregrounding learning in formal contexts *or* learning in informal contexts. The outside-in perspective studies the emergent behaviours of learners in informal settings and considers how such learning can benefit and inform learning in formal settings. This approach is prevalent in research into learning from games, use of social media and informal learning (Kafai and Resnick 1996; Kafai and Fields 2013; Shaffer 2007; Greenhow et al. 2009). The inside-out perspective starts by looking at the formal curriculum and considers ways of extending the learning to informal settings (Looi et al. 2010).

Our context is the city-state of Singapore in which school education is centrally planned by the Ministry of Education, and the schools follow mandated national curricula for various subjects. With the curriculum playing a central role in the school education system and for the teachers, the inside-out approach is chosen so as to achieve more tractability with stakeholders. Through a design-based research approach, we first conducted several research cycles in the 3-year completed research project entitled “Leveraging Mobile Technology for Sustainable Seamless Learning in Singapore School”. The work enables us to develop a viable innovation model (the *seamless learning model* or *SLM* in short) by working with a teacher and her class of primary school students over a period of two school years.

In the co-design process, researchers worked with the teacher to revise and mobilise 2 years' worth of the national curriculum for Primary 3 and 4 Science by considering the opportunities afforded by ubiquitous access to mobile devices. Another teacher was invited in the second year to participate in the enactment of the designed curriculum in another class. Activities were designed which sought to extend learning activities beyond the classroom. To support the continuous and long-term learning activities, the students were each assigned a smartphone with 24×7 access in order to mediate a variety of learning activities such as in-class small-group activities, field trips, data collection and geotagging in the neighbourhood, home-based experiments involving parents, online information search and peer discussions and digital student artefact creation.

When we started the co-design with teachers, we were guided by design principles of a seamless learning curricular innovation enabled by mobile technologies, which have been reported in Zhang et al. (2010). These design principles are:

- Design student-centred learning activities (to promote engagement and self-directed learning).
- Make students' thinking process visualisable (so that they can be shared and subjected to further refinement).
- Incorporate different learning modalities (to personalise learning).
- Design for holistic and authentic learning (make science learning meaningful).
- Facilitate social knowledge building (to promote collaborative learning).
- Ensure that the teacher plays the role of facilitator (to move away from didactic teaching).
- Provide an environment to integrate all learning activities (students have a hub to launch or continue their learning activities).
- Assess formatively (through the learning activities, students can receive feedback for their own ideas from peers or the teacher).
- Extending classroom learning activities beyond school hours and premises (to support the notion of seamless learning).

Each topic in the curriculum was developed in a just-in-time manner for the teachers' enactment in class. The researchers observed the classes and provided feedback to the teacher to improve the design and subsequent enactments. In this iterative process, the researchers also deepened their understanding of the design principles for application in the next round of design. There were several cycles of iteration during the first 2 years of design and implementation in two classes. Thereafter, the school decided to scale up the adoption of the curriculum to all classes in the same grade level. Thus design principles that were used for designing the curriculum for one or two classes with enactment by their teachers underwent the tests of their applicability for all classes with students of different ability levels and teachers with different beliefs, knowledge and skills in facilitating such a new curriculum. In the next section, we reported these distilled and improved design principles for producing a seamless learning curriculum that is robust and can be enacted by different teachers for more diverse classes and students.

Principles for Designing and Enacting a Seamless Learning Curricular Innovation

The key epistemological design commitments of the curricular innovation are learning as drawing connections between ideas and learning as connecting science to everyday lives and across multiple learning spaces. The curricular commitment is seamless learning and inquiry-based facilitation and learning. The technological commitments include technology for construction, technology for communication and technology for searching information anywhere anytime. The design of the learning units in the mobilized curricula for science embodies seven main design principles:

1. Design for emergent learning and for personally and socially meaningful goals.
2. Making thinking visible.
3. Plan for enough time to do learning activities.
4. Design for technology ready-at-hand (in and out of class).
5. Design for seamlessness (bridging across contexts).
6. Design alternative assessments (to test new competencies).
7. Design not for direct conversion from paper-based curriculum.

The first design principle is designing for emergent learning and for personally and socially meaningful goals. While the curriculum is necessarily structured, opportunities are sought for student's self-directed learning to stimulate their curiosity and motivation. The instructional strategies include teaching less content directly and teaching the core ideas but providing opportunities for students to explore and make connections between ideas. The notion of students possessing learning goals that are personally and socially meaningful to them is closely tied to students' intrinsic motivation of learning, self-efficacy and meta-cognition. A didactic and test-dominated curriculum tended to provide or support extrinsic goals of learning (e.g. students do the work because it is mandated in the curriculum or they learn to the test) but would not afford much room for students to develop personally and socially meaningful goals.

Curriculum design needs to be intelligently tweaked to afford more exploration and choices for students to do meaningful goal setting. Emergent learning can occur in structured tasks if the tasks allow for students to contribute through multiple learning pathways. From the experiences in designing and enacting the curricular innovation, we distil 5 design considerations for designing for emergent learning (Table 21.1).

Designs are made for students to learn in situ and make use of their process skills as they interact with the environment set in the task. Although the environment for the tasks is prescribed, the individual learning experience can be emergent. This is possible when the tasks require the students to observe the environment around them and to synthesize a diversity of ideas instead of documenting standard answers.

Table 21.1 Designing for emergent learning and for goals that are personally and socially meaningful

Design categories	Examples of designed tasks	Learning goals	Examples of learning outcomes
Authentic interaction with environment	Students to go to supermarkets with their family members and observe how items are classified. From their observations, they will create their own classification diagram. Students subsequently share their classification in groups	Students to be able to meaningfully classify items and appreciate the importance and different ways of classifying the similar items	Students will see diversity in the classification of common items they are familiar with and are exposed to ideas shared by peers. They are challenged to think of alternative ways of classifying the items they identified
Reciprocal teaching	Students to interview a family member on what he/she knows about the digestive system. Students offer alternative views and share their learning experiences with their family members	Students to reinforce and refine concepts of digestion	Students are not only able to label the organs and describe the digestive processes, they are also able to contrast digestion and digestive processes. They are also able to identify how the digestive system works with other body systems. Students get to explore and rethink everyday terms used by their family members and contrast them with scientific terms they learned in class and from their research
Self-documentation of learning processes	Students to design experiment to test for properties of materials and invite parents to help video record the experiment	Students to be able to design and improve experiments	Students reveal non-standard ways of experimental design and students' thinking processes that contributed to experiments that are not fairly designed

(continued)

Table 21.1 (continued)

Design categories	Examples of designed tasks	Learning goals	Examples of learning outcomes
Self-reflection	Students to complete KWL throughout the school year	Students to be able to reflect upon their learning beyond the prescribed textbook and taught content	Students asking questions that are meaningful to them and are genuine in addressing their natural curiosity. They build upon the ideas surfaced in class discussions and construct their own understanding. What that may be seen as out of the scope of syllabus is often catalyst to engage the individual in deeper learning and frequently motivates other classmates to pursue further
Building lessons upon students' contributions and needs:	Students are required to share their reflections and artefacts in class presentation. They are also required to provide constructive feedback in such presentation	Students learn from teachers and peers and reflect and improve their own work	This has a similar outcome to self-reflection but it compasses more pathways of sharing. Apart from sharing their reflection, students get to share in other ways like drawing, videos, pictures and concept maps. With multiple avenues to collect students' feedback, the resultant class discussion is in comparison richer and more dynamic. This inherently eliminates the Initiate-Response-Evaluate (IRE) model of questioning in traditional classroom.

Reciprocal Teaching One approach is to ask students to teach and learn from peers or even family members. This provides opportunities for them to switch from the role of a passive learner to one that is actively engaged in the construction and reconstruction of ideas. Through the teaching of another person, the students reaffirm, test, refine and improve their own understanding.

Self-Documentation of Learning Processes Opportunities are created for students to self-record their learning processes in performing learning tasks. Students are given the autonomy to plan and design the tasks. They will share these recordings in class and decide how they can improve their own processes after the teachers and peers provide feedback. Students are also given the opportunity to explain their decisions and ideas.

Self-Reflection Students reflect on what they think they know about the topic, and this is mainly done through the KWL tool. They state what they want to know more about and search for information to fill in the knowledge gaps. Self-reflection does not limit students to reflect upon the content taught in class. Every student is given an equal opportunity to reflect upon their learning and is free to share what they think they know. Doing the KWL is thus a continuous process and encourages students to review their thoughts as they construct new ideas. This is especially helpful in encouraging them to pursue their unique interests in a safe environment and for teachers to gain insights to the students' mental processes and learning needs.

Building Lessons upon Students' Contributions and Needs The classroom discourse is emergent as it builds upon the ideas contributed by the students. The teacher facilitates and helps the students to brainstorm diverse ideas in classroom, discusses how to connect them and then seeks some possible convergence. While achieving curricular goals, teachers co-construct ideas with the students socially and supplement teaching based on learning gaps identified. With this student-centric approach, the teacher can conduct the lesson to cater the lesson to different learning abilities and styles.

The purpose for designing for emergent learning is to encourage and surface students' developing conceptions and ideas. By engaging the students, it empowers them as their ideas are valued regardless of their correctness and accuracy. In contrast to an environment where teachers share a single perspective of how concepts should be interpreted, the emergent classroom offers the teachers more opportunities to scaffold learning from the students' perspective. Emergent learning brings about divergent perspectives and this reflects the complexity in the real world. Helping students to develop skills to converge, rationalise and rise above the myriad of ideas to construct their own understanding while accepting ideas from others is important in preparing the students for lifelong learning.

The second design principle of making thinking visible is about getting students to think and do and to represent their thinking in the form of representations, such as text, tables, sketches, animations, concept maps, etc. Students represent their developing conceptions of science phenomena. Figure 21.1 shows the KWLs created by some students.

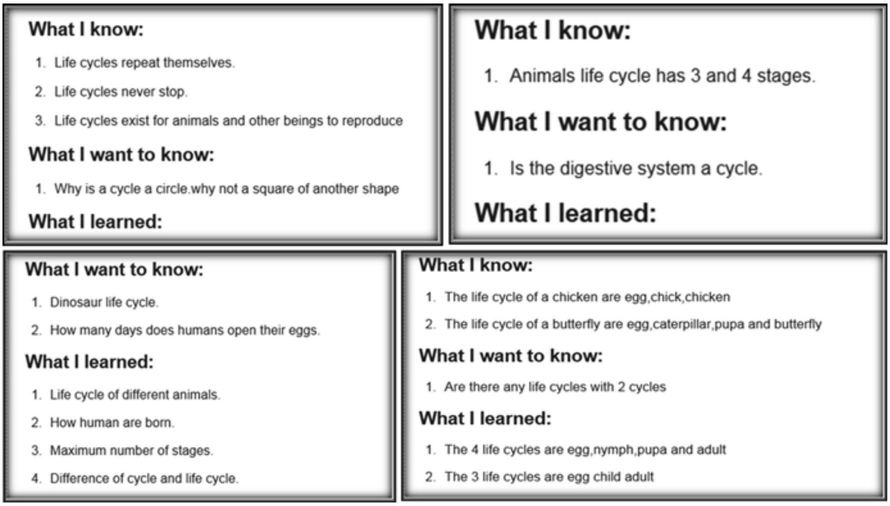

Fig. 21.1 KWLs from different students reflecting their thinking

The third design principle involves planning for enough time to do learning activities**.** As learning is not just about hearing, remembering and reproducing, there should be enough time for students to do each small chunk of learning activity so that they can be involved in some form of sense-making or personal inquiry, similar to flipped classroom, but the students generate the content at home and connect in the classroom. The teacher orchestrates the classroom discussion to string their work together.

To make time for meaningful and constructive discussions in class, the lessons are designed for students to generate ideas and complete assignment outside curricular hours. For example, students are tasked to self-document experiments, conduct research, observe natural phenomenon, learn with family members and learn from their environment. This is similar to the concept of a flipped classroom but our design focuses on students' generative ideas and not just watching videos passively. Students submit their work online which teachers can view prior to the lessons to help them develop the lessons based on the students' contribution. This also gives the teachers ample time to prepare to help students bridge and connect the diverse ideas generated as a class.

To help teachers in orchestrating the lessons, they can learn and expect how a lesson will be enacted through the experiences of mentors and fellow teachers, prior to their own lesson enactment. Teachers new to the mobilized curriculum can visualise how the lesson should be enacted. It also helps them to anticipate challenges and student responses in the classroom. During TTT, lesson plans are discussed on the flow and procedure of the activities. Teachers who have enacted the lesson in the previous year share their experiences of enacting the lesson and students' learning difficulties. The teachers may collectively discuss different approaches to how the lesson may be enacted. Through role playing and modelling of some activities, teachers get another perspective of how a lesson can be facilitated. As an example, one of the teachers shared how she learned to enact differentiated instruction with the sharing during TTT. Before TTT, she only checked on the teaching progress with other teachers, but now she listened to how other teachers shared their experiences in enacting lessons in sufficient detail with classes with different academic abilities. Benefiting from such sharing, she became more confident in differentiating the curriculum to the two diverse academic abilities she was teaching.

Indeed, mentors provided support to newer teachers by discussing with their mentees prior to the lesson and providing just-in-time assistance and feedback during the lesson. More than observing the classroom lessons, mentors and mentees worked dynamically together to improve the lesson at real time. The breadth of scaling the curriculum innovation became an enabler to build common experiences among the teachers in this community of practice. This proliferation of the shared experiences deepened teachers' skills, knowledge and attitude and added depth to the scaling. The Head of the Department commented that the trigger for transformation in one of her senior teachers in becoming more open-ended and student-centred after more than a decade of teaching was the outcome of pairing with another teacher mentor. The teacher mentor was a peer buddy who could shape the attitude of the mentee who saw that the mentor was there to help and not to assess their performance. This senior teacher confirmed our observation when she said that her mentor has provided valuable help and assistance in her enactment of the lessons.

The fourth design principle concerns designing for technology ready-at-hand (in and out of class), that is, design activities that can leverage the affordance of the technology at hand anytime and anyplace. For example, students can search for information in class and out of class as and when they need help in clarifying ideas and reaffirm conceptions. Students tend to lose interest very fast, and when they do not have ready access to the technology, the opportunity for just-in-time learning cannot be capitalised.

The fifth design principle is designing for seamlessness (bridging across contexts). It involves designing activities that students can continue to do at home, where they can draw on information, resources and people in a different context and space to learn continuously. Tapping on the importance of out-of-school learning and students' choice and agency in learning, we encourage/scaffold students' continual learning outside of the classroom through some of the curricular activities.

Self-directed learning would be incomplete if the informal learning component was not taken into consideration. Helping pupils to develop self-sustaining interests for learning could start within the formal curriculum. A curriculum with a heavy emphasis on didactic instruction would tend to breed pupil dispositions to see learning as memorization, rather than understanding. Thus, the teacher had the important role of guiding students to make meaningful connections between their informal learning and their knowledge learnt through the formal classes. However, a teacher felt active parental participation would help student connect their learning across the informal and formal learning spaces.

In the Singapore context, there seems very little room for informal learning. Even after school, the students' time was filled with extended activities of formal learning, such as going to tuition centres and private tutoring. Under this culture, it seemed quite challenging to help and motivate students to develop "dispositions" toward self-sustaining interests.

The sixth design principle is designing alternative assessments (to test new competencies). The use of technology ready-at-hand engenders new competencies which require new forms of assessments. For example, assessments can be from doing work digitally, rather than via paper and pencil. Submission of assignments digitally prior to class allows teachers to identify class learning gaps and help students learn from and build on one another's work rather than relying on teacher's standard answer. One teacher shared her experiences in the use of alternative assessments: "We discuss. I think it is good because we don't look at model answer in the activity book anymore. Now it is like, as a teacher, what will you tell the students I think among us there are more discussions I think because of the nature of the question, we have no choice but to ask. That helps us in a way. We tend to throw out ideas, we tend to see certain ways of answering and how think about certain concepts."

Students might also be assessed for self-regulation and self-directed learning skills. The mobilized curriculum (MC) would lead students to perform well in their usual summative assessment as well as other measures (which researchers need to measure, e.g. their self-regulation skills, their ability to link informal learning to formal learning). A related issue is that the MC should also equip students to do as well on typical worksheets. Digital MC should not totally substitute paper worksheets or assessments. The issue is not about the quantity but the quality and meaningful use of the worksheet to help students construct ideas. While traditional assessments focused on assessing students' ability to reproduce what the teacher and textbook presented, MC assessment, both in digital and paper format, looks into helping students to record their ideas and comparing them with peers and consolidating learning from class discussions. For example, in a traditional worksheet to test students' ability to classify, students are given a fixed list of items and categories to record the standard answers. This fails to accommodate the real-life experiences of individual students and limit the richness in the diversity of their ideas. In the MC worksheet, students need to situate themselves in a common real-life environment but identify authentic items for classification. To allay fears that students doing MC are less prepared to do well in the paper examinations, MC worksheets were also designed to help students develop thinking and process skills required to prepare them for the rigours of national examinations.

The seventh design principle is designing not for direct conversion from paper-based curriculum. The technology medium provides affordances for learning in more engaged, interactive or collaborative ways than what the paper-based curriculum affords. Mobilising curriculum is not about digitising current school teaching resources and lesson ideas. It requires a shift in pedagogy and transformation of classroom culture as well as teachers' and students' mindset. While it is easy for schools to digitise current paper-based curricular materials, this usually does not lead to transformation of teaching and learning with technologies. Apart from appropriating the affordances of technology, the MC requires a detailed review of current teaching practices and school-based curriculum. Learning outcomes should be enhanced by technology and not just using technology to replace current materials and hoping to achieve the same outcomes. For example, in a paper-based curriculum where the students are required to record experimental findings in an experimental setup that is highly prescribed by the teacher, digitising the recording tool will not enhance learning for the students. Such practices will also not enhance the quality of the learning experiences, and in fact, such use of technology will only increase the time required without any value added. In order to better the learning experience, the experimental design should also be decentralised. This allows for diversity of ideas as well as opportunities to encourage students' creativity and generation of ideas.

Curriculum Enabled by Smartphones

The designed curriculum was developed with the use of software apps on the GoKnow™ MLE (Mobile Learning Environment) that runs on a Microsoft Windows Mobile operating system. The GoKnow MLE enables teachers to create differentiated lessons easily via its online learning management system, GoManage, and it enables students to easily personalize their learning experiences (Looi et al. 2009). MLE supports teachers in creating complete, coordinated, curriculum-based lessons that employ multiple media and applications (e.g. text, graphical, spreadsheet, animations and the like). It is an environment in which students engage in the specified learning activities and create various artefacts. It includes software tools such as:

- KWL (what do I already know? What do I want to know? What have I Learned?) to allow students to learn in a self-regulated way
- Stopwatch that supports timing of events
- Sketchy™ as an animation/drawing tool
- PicoMap™ that allows students to create, share and explore concept maps

The researchers and teacher designed a total of 12 MLE units in the 2 years of intervention. It was noteworthy that we did not design the whole curriculum in one go before the intervention commenced. During and after each design-enactment cycle for an MLE unit, we reflected upon the lessons and applied such understanding to inform the design of the next MLE unit. In addition to offering a logical flow for learning the domain knowledge, we had progressively incorporated various types of inquiry/seamless learning activities, from simpler to more demanding ones. This was to facilitate the students' gradual changes in their habits of mind moving toward learning seamlessly. We provide a categorization of the ten major types of smartphone-mediated activities in Table 21.2.

Table 21.2 Types of mobile-assisted activities incorporated in the MLE curriculum

Activity ID	Activity type	Mobile affordances
KWL	Self-regulation of learning progress	KWL
Anim	Animation creation	Sketchy
Ph	Photo taking	Built-in camera
CM	Concept mapping	PicoMap
Dsc	Online artefact sharing and discussion	Blog/mobile forum
Trp	Field trip	Video, photo and note taking tools
Exp	Scientific experiments	Video, photo and note taking tools
Par	Activities with parental involvement	Videos and other tools
Web	Web search and media playing	Internet Explorer, YouTube app
Col	In situ multimedia content creation and forum discussion	Collnq (with geotagged postings, each served as a discussion thread)

From Wong (2013) …

Progression of the Mobilized Curriculum

SLM advocates continuous learning by the students inside and outside of the classroom. The curriculum incorporates components where they use their personal mobile devices to do planned activities at home or outside of the classroom and where they also learn in. In the first stage of the experimental implementation in the school, the focus was on developing a school-based student-centric curriculum. Student learning was foregrounded in this phase where their interactions with the designed activities are dynamically reviewed by the researchers and the teacher involved. This initial phase also examined the students' learning informal environments outside the classroom and the feedback from the parents on their child's learning during the intervention. As a precursor to developing the curriculum, the researchers and the teacher spent time to understand the teacher competency, the learning needs of the student, the school culture and the national curriculum goals. In Year 1 when the first version of the curriculum was developed, there was only one teacher and one class of 38 students involved. This provided the flexibility needed in the design of the lessons and integration of technology into the mobilized curriculum. Flexibility was essential at this stage as changes are needed to be made to lessons as they unfolded, with a deepening understanding of the students' learning needs. Although the lesson package consisted of a series of lessons organized into 12 topics for Primary (Grade) 3 and 4, the design team constantly reviewed and redesigned to incorporate changes that took into account students' learning gaps and outcomes. The fluidity resulted in a series of short design cycles that occurred during the lesson enactments.

In the subsequent stages when the curriculum was scaled to all 8 classes of 300 students in the grade level, the reviews of the design were catered to accommodate for teacher diversity and the relationships between the planned, enacted and experienced curriculum. While teachers were the new focus, the focus on student-centric curriculum was not diluted but strengthened. The adaptation of the curriculum design considered the different teaching experiences, pedagogical habits and epistemological orientation of the teachers. The different enactments of the designed curriculum in the classroom were documented and analyzed. Similar to the first phase, we documented how the enacted curriculum affected the learning experiences of students with different abilities. This led us to the intervention of levelling up the pedagogical practices in the classroom to enact the mobilized curriculum designed in the first stage. At the end of this stage, the researchers and school leaders concurred that a differentiated curriculum would better align the enacted curriculum with the planned curriculum to meet diverse learning and teaching needs.

In stage three, the curriculum was reviewed to incorporate best practices and approaches documented from the previous phase. The product of this review was further enhanced by the development of differentiated teaching and learning strategies by three ability groups (higher, middle and lower academic abilities). Teachers and researchers worked together to craft a revised set of lesson plans and school-based worksheets. At this stage, teachers would have the relevant tools to enact the lessons to get students to generate and co-construct ideas in the classroom.

The complexity of the innovation lies in the interplay between structure and flexibility. While structure is important to scale the school-based curriculum to the entire level, there must be flexibility to accommodate teachers' varying epistemological orientation, pedagogical habits and unique classroom culture. The different learning needs and abilities are key consideration in successful implementation. At the same time, the innovation has delivered the academic goals set by the school management and met expectations of parents to prepare their children for the national examinations in the future. Aligning the goals of the different stakeholders further resulted in the complexity of the innovation in the school. With the establishment of the curriculum and alignment of goals, there is still a need to continuously monitor the process of innovation, review the relevancy of the curriculum and deepen teaching practices.

Seamless Learning Scaling-Up

A framework is needed to guide the curriculum scaling-up effort to help assess whether and when the curricular innovation is ready for scaling and how we know to what extent to which scaling has taken place. One of the most cited literature on scaling is that of Coburn (2003) who defined scale as encompassing four interrelated dimensions:

1. Depth: Depth refers to deep and consequential change in classroom practice, altering teachers' beliefs, norms of social interaction and pedagogical principles as enacted in the curriculum.
2. Sustainability: Sustainability involves maintaining these consequential changes over substantial periods of time.
3. Spread: Spread is based on the diffusion of the innovation to large numbers of classrooms and schools which will adopt and adapt the innovations.
4. Shift in reform ownership: Shift requires districts, schools and teachers to assume ownership of the innovation, deepening, sustaining and spreading its impact.

At the school, we have moved from serving 38 students (1 teacher) in 2009 and 2010 to serving 300 students (6 teachers) in 2012 and 600 students (11 teachers). This almost order-of-magnitude jump in the outreach to more teachers and students requires research if that transition is to be effective. What we learned in the pilot was critically important, e.g. that SLM can be an effective pedagogical model in supporting students as they engaged in inquiry-based learning. However, in going to scale, the issue is no longer one of efficacy but one of infrastructure – how do we take an innovation that was handcrafted and make it more rugged, more robust, more stand alone and more transparent?

By the end of the academic year 2012, all teachers of Primary (Grade) 3 have enacted the curriculum. The scale-up comprises these multiple components:

1. Mobilized curricula (to lead students to self-directed learning and to bridging informal learning spaces).
2. Teacher facilitation skills.
3. Teacher readiness.
4. Student readiness including hardware and software training, cyberwellness and responsible care of the smartphones. The school developed and delivered a series of cyberwellness programmes which addressed topics such as the protection of one's identity and personal information, dealing with strangers, cyberbullying and inappropriate content.
5. Technology infrastructure, e.g. WiFi and 3G Connectivity, and availability of mobile devices in 1:1, 24 × 7 basis

Table 21.3 summarizes the scaling outcomes of the mobilized curriculum in terms of these components.

Table 21.3 Current outcomes of scaling based on Coburn's dimensions (2003)

Coburn's dimensions of scale (2003)		What have we scaled?
Depth	Deep and consequential changes in practice	Change in teaching practices, e.g. promoting deeper level thinking and learning
		Differentiated instructional design and assessment tools across the level
Sustainability	Maintaining these changes over substantial periods of time	Succession plan
		Mentoring program
		School designed curriculum
Spread	Diffusion	From one teacher to six teachers across level
		From one level to two levels
		From subject to interdisciplinary use
Shift in reform ownership	Districts, schools and teachers to assume ownership	School leaders steering innovations
		Teachers taking ownership in designing lessons

We distil the following critical success factors for making the scaling of seamless learning curricula happen:

1. Preparing for lesson enactment. The initial stages of developing SLM require co-design between the teachers and the researchers in designing the curriculum. Subsequently, when in the scaling phase of ensuring curriculum readiness, the curriculum must be ready and available for the teachers to be familiar with. The teachers need to understand the intent and objectives of the lesson plan in order to enact the lesson well. They can continue as a community of users and designers to continue to refine the lesson plans as they learned and reflected upon their enactment in the classroom.
2. Preparing for teacher readiness. In ensuring teacher readiness and capacity to facilitate the lessons, the teachers need professional development to understand the intent of the curriculum and understand the pedagogy that is needed to enact the lessons. They must also be mentally prepared to conduct the lessons at a comfort level. When they start to experience changes, they might be more willing to change their beliefs and attitudes. There is consensus that didactic forms of instruction would lead to an emphasis on memorization rather than affording the kind of flexible learning needed. The question was raised as to the amount of room to be given to students for self-directed learning when preparations for examination were also critical in local schools. In giving students greater agency for learning, the point was put forth that it was not about structured versus unstructured learning. More importantly, it should look into how teachers and students could co-structure learning in meaningful ways. That is, student-directed learning and inquiry would require more emergent structures, less imposed structures, with students and their teacher co-designing and controlling the classroom flow through an interactional process. These interactions would then lead to unfolding sustained inquiry driven by student ideas and supported by adaptable teaching practices.
3. Working with personnel and stakeholders of the innovation. Researchers can play a role as meso-level mediators to interpret and influence the school leadership's goals, objectives and drive. The principal might have certain directions for the innovation, but not to a degree of specificity that is asked for by the teachers. We, as researchers, act as the intermediaries to help map broad directions into feasible and implementable paths for the teachers but eventually to fade away after the teachers become curriculum leaders. Teachers should eventually become curriculum leaders, taking over ownership gradually.
4. Leverage on family support: Parents play an important role in endorsing their child's learning experience outside school. The curriculum design can only provide opportunities for students to extend their spaces from school to home but the delivery of the learning outcomes depends on the parents' support and participation.
5. Technology usability and sustainability: Technology is a learning partner to support the students in their inquiry processes. They should be easily accessible, dependable and relevant to the students' digital lifestyles. At the same time,

it can meet their learning needs and social lifestyles for them to naturally sustain the use of the technology. The design of the task involved must intersect the various components of school learning, personal and social interests. The cost of the technology must remain affordable to the students (or their parents) and the school for the innovation to be sustainable.

Conclusion

In this curricular innovation on mobile learning, we have developed models for transforming the seamless science learning curriculum by: (1) harnessing the affordances of mobile technologies, (2) provision of technology infrastructure, (3) gaining organisational support for enactment of mobilized curriculum and (4) teachers' professional development. During the pilot phase, we worked with 1 teacher for a grade level 3 (P3) class in 2009 and 2 teachers for two grade level 4 (P4) classes in 2010.

Because SLM demonstrated increased student achievement, the school decided to scale up the roll-out of the transformed curriculum to all the eight P3 classes, by doing the planning in 2011 and doing the scaling in 2012. The next step in the research and implementation trajectory brings us to scaling research which seeks to make research count in practice. The goal is to study the adoption and the adaptation of the curricular innovation as it is scaled to more classes, levels and subjects and to document the benefits of balancing fidelity of implementation with adaptation to dynamic local contexts. The programme of research enables us to articulate the SLM curriculum, the supporting resources and the teacher learning and professional development models with analysis of their impact, efficacies as well as weaknesses. The scaling research will establish a model of scaling that recognizes: (1) the range and diversity of teachers' local needs as well as the necessary adjustments they need to make in order for the innovation to be useable and effective and (2) how the school can support them to adapt the innovation and yet retain the essence of its efficacy.

We hope that our narration of the ongoing research journey from innovation to practice and to scale can inspire other research initiatives that will address the multi-term, multi-pronged, multilevel and systemic aspects of school-based innovations and that at the same time, advance theory, frameworks, design principles, resources and strategies for effective and sustainable mobile learning.

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Part IV
Seamless Learning in Social Contexts

Chapter 22
Fragmented yet Seamless: System Integration for Supporting Cross-Context CSCL Scripts

Dan Kohen-Vacs and Miky Ronen

Abstract Complex multistage pedagogical activities may address different planes (temporal, social, physical) by different pedagogical strategies. Since there is no comprehensive technological support for all possible pedagogical practices, activity phases may be supported by different technologies, adapted to the specific needs of the stage. As a result, the implementation of such activities would be technologically "fragmented" since data collected with one system will not be available for immediate use in another environment. The technological fragmentation may not only obstruct the enactment of such activities but even discourage teachers and prevent them from designing rich pedagogical experiences supported by different technologies. Therefore, in order to provide a seamless learning experience, there is a need to ensure continuous data flow between the activity phases enacted with different technologies. This chapter presents our ongoing efforts to cope with the challenge of integrating various TEL environments in order to support the design and implementation of cross-context, multistage collaborative activities.

Introduction

The design and enactment of a learning activity is challenging and demands dealing with pedagogical, logistical, and technological issues (Dillenbourg et al. 2012). The design process starts by identifying the pedagogical goals, later translated into specific learning tasks and interactions performed by individuals or groups of students across the learning phases (King 2007). The tasks could be manually assigned by the teacher or set automatically according to the students' personal or social attributes like the student's role or its social affiliation (Dillenbourg and

D. Kohen-Vacs (✉)
Center of Learning and Knowledge Technologies (CeLeKT),
Linnaeus University, Sweden
e-mail: mrkohen@hit.ac.il

M. Ronen
The Department of Instructional Technologies,
Holon Institute of Technology (HIT), Israel
e-mail: ronen@hit.ac.il

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Jermann 2010). Some pedagogical strategies nominate team leaders granted with the ability to autonomously select and assign tasks and interactions to themselves and to their peers while being organized in small groups (Alexander 2006). Learning tasks could be performed across locations corresponding to a practiced pedagogical approach implemented along the activity phases. These tasks could be enacted beyond the boundaries of the traditional classroom aiming to provide a learning experience that is practiced in an appropriate educational setting (Milrad et al. 2011). This kind of structure should be addressed during the planning process requiring designers to cope with challenges involving the definition, synchronization, and integration of multiple and unique learning phases which could be set with various social, temporal, and physical attributes. Such plan should eventually transform into a single and coherent multiphase learning path.

A collaborative script is a detailed description of a multiphase pedagogical strategy, which describes the attributes and settings of a learning activity. Each of the activity phases can include any number of interactions to be performed by the students. A script addresses five main attributes: the learning tasks, group composition of students, task distribution within and among groups, the modes of the interactions between the participants, and the timing of the phases (Dillenbourg and Jermann 2010).

In a complex multistage script, the various activity phases may be supported by different technology-enhanced learning (TEL) tools adapted to specific goals in order to alleviate the pedagogical and logistical challenges. Such script can define the type of Information Communication Technological (ICT) devices that should be used during a specific phase. For example, a learning script could include an outdoor phase, requiring the use of mobile devices followed by an indoor phase supported by laptop or stationary computers (Huang et al. 2011; Spikol et al. 2008). Pedagogical interactions that are technologically supported normally result with students' or teacher's contributions of digital artifacts stored in databases connected to one or more TEL environment. The digital information is formatted, organized, and interrelated within the databases' structure according to the activity description and its interrelated phases detailed in the learning script.

The technological support provided to a learning activity by TEL environments is pivotal when considering an enactment of complex pedagogical designs aiming to provide students with a seamless and meaningful learning experience (Tchounikine 2011). A successful enactment of such designs could broader students' opportunities to be introduced with new learning experiences practiced across phases by various social organizations at different locations (Vogel et al. 2014), allowing them to switch between learning settings easily and quickly using their own ICT devices (Chan et al. 2006).

Wong and Looi specified ten mobile seamless learning (MSL) dimensions that characterize possible mobile learning situations (Wong and Looi 2011; Wong 2012):

(MSL-1) Encompassing formal and informal learning
(MSL-2) Encompassing personalized and social learning
(MSL-3) Learning Across time
(MSL-4) Learning Across locations
(MSL-5) Ubiquitous access to learning resources

(MSL-6) Encompassing physical and digital worlds
(MSL-7) Combined use of multiple type of devices
(MSL-8) Seamless switching between multiple learning tasks
(MSL-9) Knowledge synthesis
(MSL-10) Encompassing multiple pedagogical models

Most of the dimensions specified by the MSLs may be also evident in complex learning activities that are not necessarily supported by mobile technologies. For example, a multiphase collaborative activity could be performed in classroom or at home by participants organized in various types of groups using regular stationary computers. Hammer et al. (2010) described such a learning activity that consisted of students' interactions across different physical planes (classroom and home) along four activity phases. Students' interactions included self-enrollment to a group, submission of group artifacts, peer product assessment, and finally their participation in a session in which results and reflections were presented to the entire class.

As mentioned, complex multistage pedagogical activities may address different planes (temporal, social, physical) by different educational strategies. Since there is no comprehensive technological support to all (existing and forthcoming) pedagogical practices, each of the activity phases may be supported by different technology adapted to the specific needs and goals of the stage. As a result, the implementation of such activities is technologically "fragmented" requiring system integration in order to support the dataflow within the activity phases aiming to provide a seamless learning experience (Hoppe 2009).

This chapter presents our efforts to cope with the challenge of integrating various TEL environments in order to support complex, cross-context pedagogical activities. We describe the considerations involved in the design and enactment of such fragmented activities including their various attributes and settings. The process is illustrated by a sample of pedagogical activities enacted in real educational settings with more than 120 undergraduate and graduate students using different integrated technological environments (Milrad et al. 2011; Kohen-Vacs et al. 2011, 2012a, b). Each of these cases, we will demonstrate how we coped with the design challenges while establishing an ecological framework which involves the coexistence of pedagogical, logistical, and technological aspects.

General Requirements Towards Designing of a Complex Script

The design process of a learning activity should start with the identification of the stakeholders. The primary stakeholders include the educational policy makers, teachers, and students. In addition, technological developers and technical supporters are also considered as stakeholders. Their involvement should start from the design phases and continue through the implementation of the activity. Their role is crucial since it requires them to anticipate, avoid, or minimize difficulties before the actual enactment of the activity.

Stakeholders' involvement during the design process starts by suggesting their unique or common personal goals related to the learning activity. It continues with mapping, negotiating, and consolidating the suggested goals to a focused scope (Alexander and Beus-Dukic 2009). This is required in order to avoid a design process that might result in a complex set of activities including numerous, different, and not necessarily interconnected learning phases.

The next design stage includes mapping of the technological affordances and the identification of the possible challenges involved with adopting the specific technologies for supporting the learning activity. For example, teachers who enact the activity may suffer from lack of sufficient technical literacy that will prevent them to efficiently assist their students. Learning environments by themselves could lack the sufficient technical infrastructures preventing the technological support along the learning path. These kinds of challenges could be tackled by a process, which consists of a pre-evaluation of the educational environment including its human and technical aspects.

In the following section, we will present the students' generated content and their reuse along the activity's phases as emerging learning objects (ELO). These types of students' interactions should be considered while designing complex, cross-context pedagogical activities supported by interoperable data that is generated by the uses technological environments.

Learner-Generated Content, ELOs, and Their Reuse in the Different Phases

Multistage learning activities may use a single or multiple TEL environments in order to support teacher and learners interactions across their phases. Data flow is initiated when teacher or students interact across one of the activity phases with an ICT device. These interactions could be tagged with contextual metadata including temporal, geophysical, and social information. Data is formatted and stored within a database used by the TEL environment. Materials that are contributed by students in a multistage activity may become learning resources by themselves. Such resources are referred as ELOs (Hoppe et al. 2005). ELOs can be contributed by individuals or groups. The data storage should reflect the origin of the ELO and its relation to the activity script. When the activity phases are supported by different TEL environments, additional metadata should reflect the source (technological environment) of this ELO.

Multistage pedagogical activities with their various types of interactions could be described by different Educational Modeling Languages (EML). Exiting specifications such as IMS-LD may not appropriately address the data flow within a Computer-Supported Collaborative Learning activity (Bordiés et al. 2012), especially when modeling a script which addresses contributions that are intended to be used as ELOs.

When different technologies are used across the activity phases, the information that is collected in one environment cannot be necessarily transferred and automatically used in a second environment. As a result, the learning activity may become technologically fragmented causing logistical difficulties and therefore also disrupting the pedagogical process along the learning path. In order to ensure a *seamless* process, the systems involved should technologically interoperate.

The technological support of a learning activity should address the possible types and sizes of teacher and students interactions performed along the activity. The nature of these data contributions can influence designers' considerations and the selection of technological infrastructures to be used along the learning activity. Activity interactions could be in a form of text, sound, pictures, or as a combined multimedia. The type and size of such contributions would require the use of dedicated user interfaces supported by backend network and storage abilities. For example, an activity phase which requires students to submit text normally requires a simple user interface, a modest amount of bandwidth, and a simple approach of data storage. Multimedia interactions will require a more sophisticated UI approach, a wider bandwidth, and a storage approach dedicated for large objects. Teacher and students interactions could be reused across the activity phases supported by different environments requiring a detailed technological approach to enable data interchange. This approach should reflect both the technical aspects (like size, type, and involved systems) and also the pedagogical context in which the contributions occurred as detailed in the EML.

The following section presents sample cases of multistage collaborative activities supported by integrated TEL environments which include both technical and pedagogical data interchange which enables to cope with the technological fragmentation of the learning activity.

Sample Cases: Integrating Mobile Elements in CSCL Scripts

The following examples demonstrate the integration of mobile elements into CSCL scripts. In these examples, the Collaborative e-Learning Structures (CeLS) environment was used to design the script and to support the activity. CeLS is a web-based environment designed to enable teachers to design, enact, share, and reuse collaboration scripts and incorporate them in the existing instructional setting for any subject and level, from elementary school to higher education flow (Ronen and Kohen-Vacs 2010). In the first two examples, Mobile Collaborative Learning System (MoCoLeS) was used to support interactions performed outdoors (Vogel et al. 2010). This system supports the implementation of location-based activities enacted by GPS-enabled mobile devices. In the third example, the script included a phase supported by a mobile personal response system (PRS) and a phase during which students used a dedicated environment for a self-diagnosis.

For each of the examples, we shall present the instructional goals, the activity script and its phases, the technological support for each of the phases, and the potential and challenges of combining different technologies in order to support the data flow.

My Village

This example presents an activity designed for elementary school, aiming to familiarize students with the history of their hometown and to strengthen their relations with their local communities. In order to address this goal, the learning and activities should direct students to visit important landmarks and to explore them. In addition, students may meet with key figures in their own towns like city founders' senior citizens and public servants. Therefore, some of the activities should span beyond the classroom boundaries, being performed in various sites, while content collected from these sites would be used and referred in various situations happening across different locations like at home or in classroom sessions. The activity that aimed to address these goals was supported by a script designed with the CeLS environment (Milrad et al. 2011). The activity script consisted of four phases.

In the first phase, students enrolled to small "messengers" groups assigned to various sites of interest. The grouping of students into various groups was supported by the CeLS environment.

In the second phase, each group arrived to the assigned site and collected and submitted information (GPS location, pictures) and queries about the site. This phase was performed via MoCoLeS, using a mobile device.

In the third phase, the groups changed roles and served as "explorers." Each group was presented with the information and queries previously contributed by their peer "messengers" about a site. Group members were challenged to explore the site attempting to provide answers to the messengers' queries using various resources such as Web sites, books, and interviews of relevant people or family members. This phase was performed as homework. Phase three included an online discussion between the "messengers" and the "explorers" until all queries are answered. "Messengers" could present new questions.

The last phase included a combined representation of various types of students' gathered contributions and interactions like tables, photo albums, and digital.

Figure 22.1 presents an overview of the script and the technological support for its phases.

Usability in Campus

This example presents an activity designed for an undergraduate course on usability (Kohen-Vacs et al. 2011). The activity included an indoor phase conducted at classroom and at students' homes. During this phase, students interacted synchronously and asynchronously from their stationary and laptop devices. In addition, that activity included an outdoor phase in which students interacted with their own mobile devices. During this activity, our research efforts focused on integrating the two approaches in order to explore new ways to support the design and enactment of collaborative pedagogical scripts that are performed with stationary computers and mobile devices both in the classroom, in outdoor settings, and at home

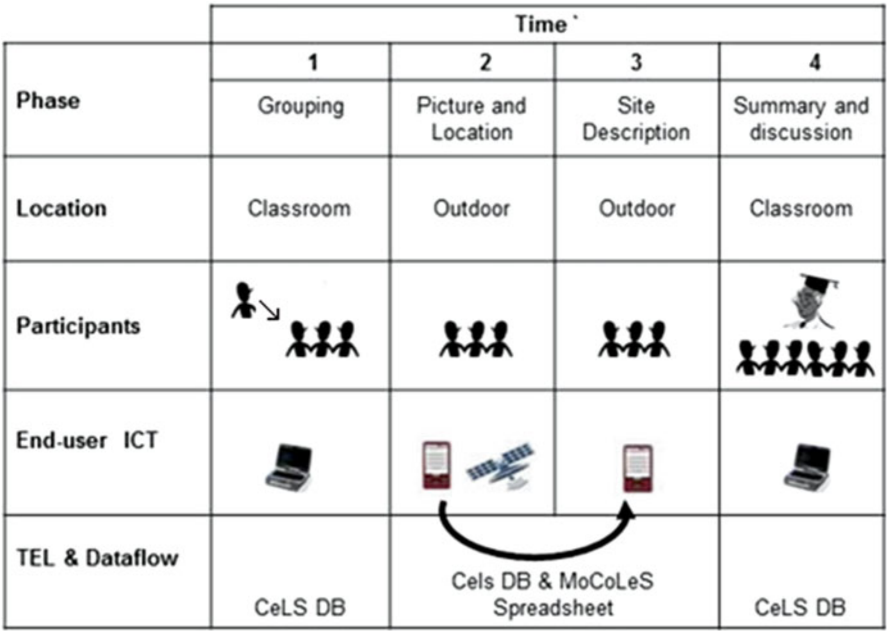

Fig. 22.1 Overview of the My Village script

The course in which the activity was enacted aims to familiarize students with the concepts and principles related to usability, to develop their ability to identify usability problems, and to propose adequate solutions to these problems.

One of the major instructional goals of this course is to raise students' awareness to usability issues involved in any aspect of real life. In order to address this goal, the learning and activities should direct students to explore real environments and to identify possible usability issues. Therefore, part of the activities should span beyond the physical boundaries of a classroom, being performed in various sites, while the content collected from these sites would be used and referred to later, at home or in class sessions.

The activity aimed to address these goals was supported by a script designed with the CeLS environment and consisted of five phases requiring students to interact across locations using various technologies (Kohen-Vacs et al. 2011).

The first phase was performed outdoors using smart phones (based on Android operating system) supported by the MoCoLeS. Students were organized in small groups and were challenged to tour the campus and to identify usability problems. Each student submitted one picture representing a usability problem and a short description of the problem. The system automatically recorded the location data, the timing and the identity of the submitter. In addition, students were required to suggest key words which best describe the problem, using the concepts and principles that have been introduced in the course.

In the second phase, the members of each group selected the best item produced by their group and submitted this item as their group artifact.

The next phases were performed as homework during the next days, using the CeLS environment.

The third phase focused on analyzing the tagging; each student was presented with four of the usability problems documented by the other groups and was asked to select up to three tags from a given list, that best describe the problem.

In the fourth phase, each participant was presented with all the other groups' artifacts and their tagging and was requested to select the best and most significant problems represented by the pictures and the cases that were best tagged by the peers.

In the fifth and final phase, the results of phase 3–4 were presented: the competition results and the class collaborative tagging. This phase included an open online discussion.

Figure 22.2 provides an overview of the usability in campus scenario and its phases the technologies used.

The enactment of the script required integration between two environments. The data that was recorded and contributed to MoCoLeS outdoors (phase 1), including picture reference, descriptive text, geolocation, and time, was stored in Google Fusion Tables. This data was then migrated to the CeLS database (phases 2). This migration was performed by a dedicated CeLS data fetcher module that imported data records into CeLS and tagged them according to the CeLS script information including the activity identifier, phase identifier, and interaction identifier. This tagging was essential in order to enable the reuse of data across the activity phases according to the modeled activity manifested in the script.

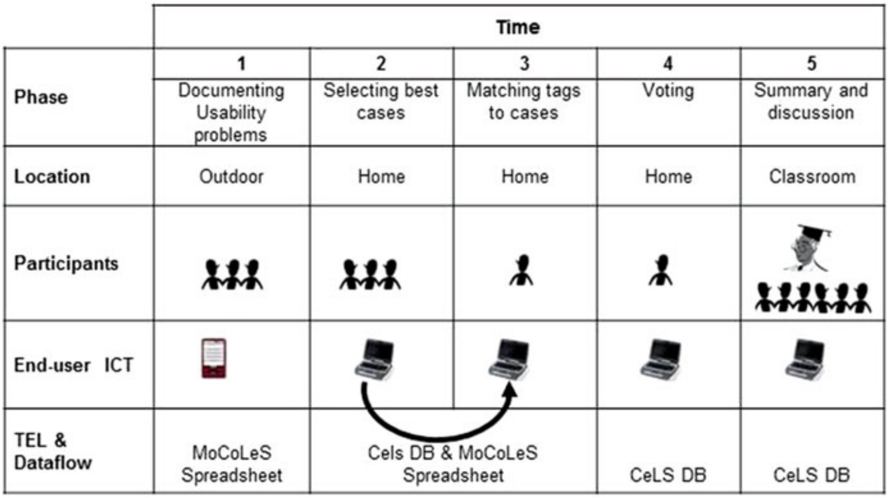

Fig. 22.2 Overview of the usability in campus script

The integration of the systems was crucial in order to prevent the fragmentation and to ensure a seamless learning experience throughout the activity phases, as was indeed indicated by the evaluation study performed with the students who participated in the activity. In their comments, students mentioned the limitations of the mobile technology stating that it should be used only whenever necessary. Students favored the option of performing the more demanding and complex conceptual tasks in the home environment at their own pace.

Negotiation Styles

This example presents an activity designed for undergraduate and graduate courses dealing with Negotiation and Conflict Management (Kohen-Vacs et al. 2012b). The activity included indoor phases in which students interacted with each other with various TEL environments using their stationary, laptops, and mobile devices. During this activity, our research efforts focused on enabling students to interact with ELOs along a cross context a fluent learning flow.

The activity was enacted in a course in which one of the principal topics deals with "negotiation styles," as defined by Rahim (1983). The instructional goals are to familiarize students with negotiation styles, to develop their ability to argue according to a style, to develop their ability to associate a negotiation statement with a style, and finally to provide them with a practical tool that enables them to negotiate according to different styles during their daily lives. In order to address these goals, the learning and activities should confront students with various typical situations requiring them to practice their own negotiation style.

The activity that aimed to address these goals was supported by a script designed with the CeLS environment (Milrad et al. 2011). In this script, CeLS was used to support the asynchronous interactions while the SMS-HIT (PRS) supported real-time class interactions. In addition, students used a dedicated Negotiation Style Identification software application (NeSI). The activity script consisted of four phases.

The first phase of the activity was conducted in the classroom. It started with the teacher's introduction of Rahim's five negotiation styles: obliging, compromising, integrating, avoiding, and dominating (Rahim 1983). At this point, each student was requested to identify his/her own primary and secondary negotiation style. This approach aimed to enhance the understanding of the different concepts by relating their implementation to a personal situation as a motivational strategy. This phase was performed by SMS-HIT PRS using students' personal mobile phones. The information contributed to SMS-HIT was migrated into CeLS database for further reuse in the next phases.

The second phase was conducted at home or elsewhere in asynchronous manner. The goal of this phase was to develop students' ability to argue during a negotiation process according to one of the styles. Students were presented with a buyer-seller pattern scenario (Claycomb and Frankwick 2012) normally used as a traditional way to train negotiators. In this case, the scenario presents an employer-employee situation (job interview) that is relevant to the students' real-life experience. Each student had to express an argument reflecting his/her declared negotiation style from both positions, once as the employer and once as the employee. Students' statements were submitted to CeLS using a dedicated interface, tagged and saved within the database for future reuse in the next phase interactions as ELOs.

The third phase was conducted asynchronously as homework. The goal of this phase was to foster students' understanding of the styles and develop their ability to relate statements to styles. Students were presented with several peers statements and were challenged to match them to the corresponding negotiation styles. Phase was carried out via CeLS, enabling students to selectively reuse data previously submitted by their peers (ELOs). The two last described phases include interactions involving with various MSL dimensions.

The fourth phase could be conducted at home or in classroom settings from various types of devices in asynchronous manner. The goal of this phase was to compare the declared personal negotiation style with the profile diagnosed by an objective measuring tool. Students filled-in a validated questionnaire designed to diagnose the personal negotiation style (Rahim 1983). This action was performed by NeSI, a software tool that provides an immediate representation of the personal profile. During the phase, students' used stationary and portable devices for diagnosis supported by the NeSI application.

The fifth and final phase took place during a face-to-face class session. The goal of this phase was to summarize and reflect upon the entire learning activity. Students were presented with a comparative representation of their declared and diagnosed negotiation styles. In addition, students were also presented with the statements written during phase 2 and with a comparison between the intended style of each statement and the ways that the peers identified the statement. The class discussion focused on the similarities and differences between the declared and the identified styles of the statements and the possible reasons for discrepancies. The representations of the data that was collected from the activity phases are provided from the CeLS environment.

Figure 22.3 provides an overview of the Negotiations Styles script and demonstrates the implementation and integration of the technological environments used to support the script enactment.

The enactment of this script demonstrates a combined use of three environments. The first two phases required integration between CeLS and SMS-HIT. SMS-HIT stored its information in a dedicated database that included the identity of participant (represented by IP or caller ID), the time of interaction, and textual information. The data was fetched by CeLS and integrated within its database. In this case, the fetching process started by a CeLS request to SMS-HIT which included the reference of the activity that its data should be imported. This request triggered a response that included the SMS-HIT stored information. The restored data was assimilated in the CeLS database according to the activity identifier, phase identifier, and interaction identifier.

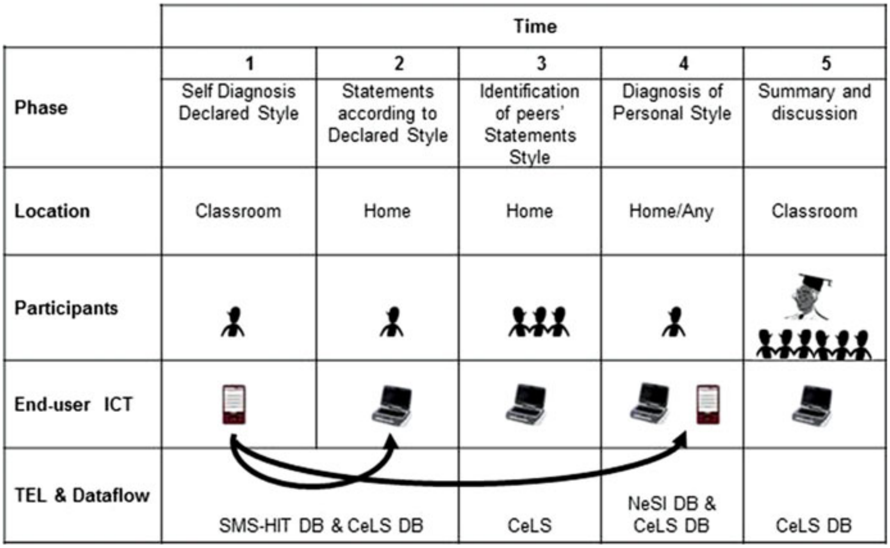

Fig. 22.3 Overview of the Negotiations Styles script

During the fourth phase of the activity, students used a dedicated Negotiation Style Identification software application (NeSI). This application provides an immediate representation of the personal profile. Personal profiles diagnosed by NeSI are stored in a dedicated database enabling to use the system in a stan-dalone mode. The diagnosis information was migrated into CeLS database for further reuse. This migration was performed by a data fetcher that sends a request to NeSI including the reference of the activity that its data should be imported. This request triggered a response that included the diagnosis records. The restored data was assimilated into CeLS database according to the activity identifier, phase identifier, and interaction identifier. The data migration also includes the users ID and numerical values that reflect the diagnosis results. This information was tagged with CeLS activity identifier enabling its further reuse (during the fifth phase).

This example demonstrates the potential of combining different technological environments in order to support collaborative learning activities conducted in the classroom and asynchronously at home (Kohen-Vacs et al. 2012a). Students reported that they appreciated the use of the mobile PRS during a face-to-face session as an important mean that provided meaningful interactivity by assimilated mobile technologies. Learners were asked about the added value of the transferability and reuse of the knowledge acquired from one phase into the continuous phases along the activity. They considered the transferability and the reuse of information as a key factor that enabled knowledge acquirement, peers' learning, learning in action during negotiation practices, and finally synthesis of new insights.

Summary and Concluding Remarks

We have presented some of the challenges involved in the design and enactment of complex, cross-context multistage collaborative learning activities supported by technology. Such activities may require the combined support of two or more TEL environments.

We presented an approach that involves an organization of a multistage activity which involves the contributions of students' artifacts during an early stage and later being reused as a learning opportunity. The students' interactions occur along different contexts and are supported by various technological environments and devices. The challenge of organizing multiphase activities which are supported by different technologies across various cross context and settings was address and considered with the existing specifications (Bordiés et al. 2012; Demetriadis and Karakostas 2008; Hernández-Leo et al. 2007). The cases that are presented in this chapter may offer new insights to be considered while designing future multiphase and cross-context learning activities. The implementation of such activities is technologically fragmented and requires systems integration in order to support the data flow within the activity phases aiming to provide a seamless learning experience. A continuous data flow requires interoperability that addresses data formatting, contextualization, and relational data storage. Such data flow process alleviates the fragmentation in a technological supported pedagogical activity by technically interconnecting the data contributed along the activity phases while pedagogically interconnecting the students' interactions.

We have presented examples of complex scripts that include various modes of students' interactions across physical planes and described their enactment supported by integrating different TEL environments. We described the aspects involved during systems integration and specified the data types that were exchanged between the interoperating systems.

The examples demonstrate the implementation of the MSL dimensions: students practiced various types of learning (MSL-1) and knowledge synthesis (MSL-9), conducted by multiple pedagogical models (MSL-10), while interacting in different social settings (MSL-2) across temporal and physical contexts (MSL-3, MSL-4) encompassing physical and digital worlds (MSL-6). Ubiquitous access was available to all data and activity resources (MSL5). All this was possible due to the use of combined types of technological devices (MSL-7), and the seamless switching and advancing through the tasks (MSL-8) was possible due to the special efforts devoted to the integration between the technologies. All the presented examples included the implementation of all the MSL dimensions along the pedagogical, logistical, and technological aspects of the learning activities.

Our future efforts will focus on the development of new TEL environments that will be integrated with new Web-based social and multimedia environments aiming to enable teachers to design and enact rich learning activities. These efforts are aligned with our previous declared objectives to empower teachers by offering them new means for implementing technological supported educational strategies.

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Chapter 23
Supporting Seamless Learning Across Individual, Collaborative, and Community-Based Learning in One-to-One Learning Age

Leon Yufeng Wu and Chen-Chung Liu

Abstract With the current advancement in information and communication technology, incorporating the already pervasive handheld devices for learning and teaching has become a common theme. The application of handheld learning devices in a one-to-one learning environment may further inform a specific need for structuring a seamless learning framework, establishing a holistic didactic paradigm, and directing future development. Within this framework, each one-on-one learning scenario would allow students to initiate and engage in learning activities individually, specifically accommodating their personal needs, preferences, and learning styles – an individual learning context. Furthermore, peers (including the instructors) may learn and teach bidirectionally via handheld learning devices in various juxtapositions and relationships provided by the shared learning platform – a collaborative learning context. Furthermore, a sense of social presence and engagement with the learning community may be engendered by transforming students' intragroup participation to intergroup interaction, thus encouraging student readiness to share more experiences in the learning community – a community-based learning context. The current chapter discusses the rationale for and the potential to structure this framework to build a seamless environment for teaching and learning with handhelds.

L.Y. Wu (✉)
Science Education Center, National Taiwan Normal University, Taipei, Taiwan
e-mail: leonwu@ntnu.edu.tw

C.-C. Liu
Graduate Institute of Network Learning Technology,
National Central University, Jhongli, Taiwan
e-mail: ccliu@cl.ncu.edu.tw

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Introduction

Fostered by the “golden age” of the Internet, the emerging technologies of information and communication have together had an immense impact upon our lives. This has also prepared the stage for developers to invent more state-of-the-art hardware to provide unprecedented experiences with those information and communication technologies which have literally renovated our means to be “connected” with people and our understanding of ways to engage in mutual communication. This process seems to be continuing to progress with unflagging rapidity.

These cutting-age inventions – handheld devices, such as the Personal Digital Assistants (PDAs), smartphones (e.g., iPhones, Android-system-operated phones, etc.), and tablet computers (e.g., iPad, Kindle, etc.) – have evolved out of many other digital technology devices. Specific trends are worth noting when comparing these devices with their predecessors. Size reduction offers greater portability and mobility (Bahr et al. 2012). Prices have been reduced which makes them accessible to more of the population (Greaves et al. 2010). Furthermore, they afford a wider range of delicate multimedia capabilities which creates a more enjoyable user experience as well as supporting the special needs of education (Bakia et al. 2012) and wireless connectivity which enhances the sense of sharing and being connected with the world (Liu and Kao 2007).

Because these characteristics present a powerful potential to transform the current state of education, researchers and educators have begun to investigate the value of handheld devices by integrating instructional and pedagogical concepts to redesign the learning environment (Roschelle and Pea 2002; Wong and Looi 2011; Zurita and Nussbaum 2004a). Among the many approaches to investigating the handheld-enhanced learning environment, the one-to-one (1:1) learning environment (http://www.g1to1.org), wherein each student is equipped with one handheld learning device (HLD), seems to be attracting the attention of many researchers (Chan et al. 2006). An HLD is not limited to the size of the device. Rather, it should be portable wireless Internet connected, compatible for the display of the multimedia-based learning materials including videos, animations, graphics, visualizations and soundings, and afforded to carry out interactive learning activities. For example, a HLD can be a laptop, a smartphone, an iPod, iPad, or any form of tablet computer. As the instructional purposes of integrating social network characteristics to build the collaborative and community-based learning environment, a handheld device (e.g., a cellphone equipped with the aforementioned features) can be recognized as an HLD.

HLDs may act as a mediator in learning activities (Wong 2012). They are also capable of providing students with individualized and ubiquitous access to content and feedback whenever and wherever needed (Echeverria et al. 2011). One more significant factor that differentiates 1:1 learning from other learning environments is that it is highly context-aware and this has an impact upon situated learning scenarios (Ogata and Yano 2004). Yin and his colleagues (2009) further suggest that the capabilities of the HLDs should enable it to jump right into a learning context when “just-in-time learning” is called for (Patterson 2003), and thus students can learn by doing (Krueger et al. 2005) by participating in a variety of learning activities through the use of HLDs.

It can thus be seen that the application of HLDs may further inform the specific need to structure a seamless learning framework to help establish a holistic scope and the future development of this "new style of learning" (Looi et al. 2010; Wong 2012). That is, based upon this seamless learning framework, each learning scenario would allow students to initiate learning activities and to do so in a context that individually accommodates their personal needs and preferences. Additionally, peers (including the instructors) may learn and teach cooperatively (Johnson and Johnson 1994; Palinscar and Brown 1984) using HLDs on a juxtaposed shared learning platform (Liu and Kao 2007). Furthermore, the sense of social presence and engagement (Remesal and Colomina 2013) of the learning community may be initiated and developed by transforming student intragroup participation to intergroup interaction, thus encouraging students to share more experiences in the learning community (Kekwaletswe and Ngambi 2006).

Such a framework should be able to mediate a variety of learning scenarios seamlessly for each individual (i.e., learning as an individual) and further stimulate and facilitate the learning process in learning activities with different dynamics (i.e., learning in small groups and learning in a community). Ideally, the learning activities should seamlessly and continuously synthesize the intended learning objectives while also allowing themselves to be shifted among different social-dynamic levels. That is, it should be possible to shift student participation or engaged learning activities seamlessly from activity to activity according to the needs for different levels of social learning. Meanwhile, the management or the computing system should be able to synchronize feedback and information that is generated by the instructors and students or by the system itself as a process of formative evaluation for greater productivity.

In section "Diverse learning activities supported by HLDs", we will analyze various learning activities facilitated with HLDs in an activity spectrum. In section "Gaps in individual, reciprocal and community-based learning", the readers will find what the challenges are when bridging different learning activities to fulfill a seamless learning scenario by identifying gaps between individual, collaborative, and community-based learning. In section "Examples of seamless learning across multiple scenarios", we will identify some of the examples of carrying out seamless learning across multiple scenarios. Conclusions and future direction are given in section "Conclusions and future direction".

Diverse Learning Activities Supported by HLDs

Many types of learning activities have been proposed and applied to enhance learning in various learning settings. These activities may be mainly categorized into three main types: individual, collaborative, and community-based learning as the three learning scenarios were most frequently discussed in the literature. Figure 23.1 displays the spectrum of different learning activities based on respective activity dynamics. The learning activity spectrum demonstrates activities that vary based upon different levels of social-interactivity involvement engaged in by students and

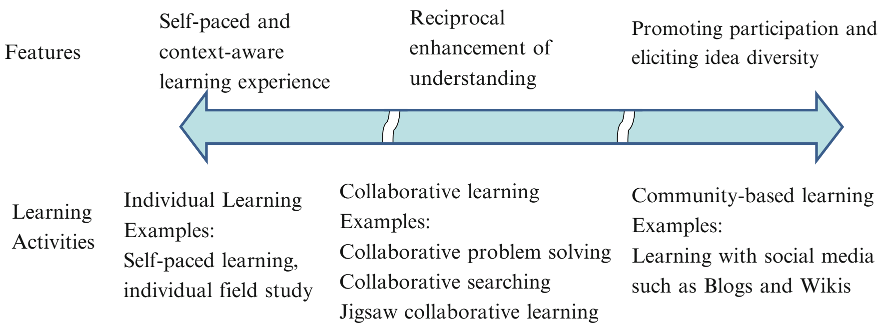

Fig. 23.1 The learning activity spectrum

instructors. Learning activities can be categorized into three types based upon those different activity dynamics in which the HLDs may play different roles in facilitating the progress of learning activities. Thus, it can be seen that the integration of diverse learning activities may need to address the different needs of various learning activities, while HLDs play various roles in facilitating and augmenting different forms of activity.

The three types of learning activities include:

- Individual learning activities: Students initiate learning activities whose course and pace are often determined by their personal preferences and needs. In addition, learning activities and situations may be initiated anytime and anywhere. These activities are often administered by juxtaposed computer software installed on the HLDs (Stockwell 2007) which handle the input and output of learning materials and the feedback of students and instructors.
- Collaborative learning activities: Students participate in learning activities as small groups of peers, facilitated by a shared learning platform which incorporates individual learning activities into a reciprocal learning activity. With collaborative learning activities, several pedagogical strategies may be applied to reciprocally enhance individual understanding of learning subjects, such as peer assessment (Chen 2010), peer tutoring, reciprocal teaching (Palinscar and Brown 1984), and collaborative modeling (Pinkwart et al. 2003), etc.
- Community-based learning activities: Students engage in social-oriented learning activities, where they may share ideas and communicate on a range of subjects, contributing to a shared learning community, within or among shared learning platform(s). Such learning activities may correspond to similar scenarios involving learning activities conducted within Web 2.0 platforms such as Wikis. Such learning activities may enhance individuals' participation in learning and elicit idea diversities.

Based on the possible different learning activities, the following subsections will discuss the diverse roles that may be played by HLDs.

Individual Learning with HLDs

The proposed role played by HLDs in providing learners with ubiquitous access to learning materials is clear. Such a role differentiates one-to-one learning from a traditional learning environment (e.g., face-to-face, teacher-centered learning in a traditional classroom) and transforms the learning process into an individualized and personalized one (Liang et al. 2005). Because of the unique mobility that the HLD can provide, learners have full control over when and where to "pull-in" the "class," in response to changing contexts as needs warrant (Wong and Looi 2011). Consequently, this individualized learning scenario, customized ad hoc by the learner, may be highly beneficial for students. The HLDs may provide a personalized way to construct what the knowledge is about and thus allow knowledge acquisition to become meaningful (Ogata and Yano 2004).

While the HLDs are applied in support of individual learning, the specific learning contexts should be taken into account (David et al. 2007). For example, there might be no difference between learning English vocabulary at home and on a bus with HLDs if the learning systems do not link learning tasks to the authentic contexts in which students are situated. However, it could make a difference for learning with arts and history where HLDs may provide timely and corresponding instructional materials synchronized with students' observation of artifacts at a museum or a library (Yin et al. 2009). Several studies have confirmed the value of this context-awareness perspective in the one-to-one learning scenarios. Vogel and his colleagues (2010) used handhelds, Web sites, and environmental sensory data to conduct inquiry-based learning about geological phenomena. Chen and his colleagues (2003) developed a handheld learning system for bird watching and observed that students benefited from it. Shih and her colleagues (2010) developed a GPS waypoint handheld application accompanied by a digital library database for learning about butterfly and wetland ecology in a field study. The above literatures support that HLDs may facilitate a self-paced and context-aware learning experience as students may use the HLDs to connect to learning platforms whenever they are needed.

Collaborative Learning with HLDs

The nature of interaction and sharing may well explain the potentials and advantages of conducting learning activities as a group whereby group members may construct a shared body of knowledge through a series of joint learning activities (Johnson and Johnson 1994). In particular, such a collaborative learning experience is supported and enabled by a reciprocal learning process. Reciprocal teaching and learning strategies were first proposed to improve reading effectiveness and comprehension. Students would take turns assuming the role of teacher to help each other approach the problem in question, so that they may both be "comprehension-fostered and comprehension-monitored" (Palinscar and Brown 1984). Similarly, HLDs may be helpful in facilitating the collaborative learning process and encouraging members to share their learning experiences and to seek additional resources to help others and at the same time share their learning achievements (Liu et al. 2009). While the individual learning activity is in progress (as described in the previous section), learners are further encouraged to work jointly on learning activities synchronously or asynchronously with their peers (Liu et al. 2009).

Scholars emphasize the need to incorporate HLDs into collaborative learning settings (Roschelle and Pea 2002) by promoting the reciprocal process such as mobile computer-supported collaborative learning (mCSCL) (Zurita and Nussbaum 2004a) and group problem solving (Liu and Kao 2007). Students use the HLDs and a learning platform to work jointly and to interact with their peers (Zurita and Nussbaum 2004b). Yang and Lin (2010) utilized PDAs in group learning activities to conduct lessons on the classification of plants. Student ability to identify and describe plants improved significantly. In the study by Lai and Wu (2006), PDAs were used to facilitate Jigsaw collaborative activities. A concept map tool was applied with the PDAs to facilitate both expert and Jigsaw group discussions. Furthermore, in the study by Chung et al. (2013), personal laptop computers were applied to support a group of student to conduct Web search. The HLDs were applied in these studies as tools to mediate the interaction and group process during collaborative learning. Students thus were more likely to participate in a reciprocal discussion process that achieves the goal of reciprocal enhancement of understanding during collaborative learning.

Community-Based Learning with HLDs

Rogoff (1994) first conceived the idea of a community of learners in which "learning occurs as people participate in shared endeavors with others, with all playing active but often asymmetrical roles in sociocultural activity" (p. 209). As social media such as Wikis gained popularity, Smith and Peterson (2007) stressed that "Knowledge is not constructed in an individual vacuum, but in the communication and exchanges embedded in social networks" (p. 278). The concept of the learner community suggests a need to facilitate community-based learning activities in order to foster self-directed learning habits. Such a perspective may also serve as the key for fulfilling the idea of building a seamless learning environment, given the putative ubiquity of social network sites such as Facebook or Wikis which have already become pervasive in our daily lives (Mazman and Usluel 2010). While HLDs may even amplify involvement in social media due to their features of portability and wireless connectivity, the integration and transformation of these social network sites for the purpose of building community-based learning environments should be regarded as imperative.

When a social network site is formed, individuals and smaller groups may initiate interaction or activities related to learning objectives, search meaningful concepts or solutions, and then contribute to the community of "the class," thus establishing the learners' social presence (Remesal and Colomina 2013). With HLDs embedded in this social interactivity, the exchange of ideas may be accelerated and students may be more engaged and responsive as mechanisms of learning activities come into play. This may also imply a potential for informal learning opportunities on the social network sites, where students choose their own learning styles and methodologies within the Web 2.0 community (Mazman and Usluel 2010) and thus construct a shared body of knowledge. Recently, the use of HLDs in community-based learning is emerging. By using a pre-developed group-drawing app and its juxtaposed platform (i.e., Group Scribbles) operated by the tablet devices, Chen and Looi (2011) observed that the community-based learning activity promoted a higher level of student participation, frequent interaction, and instant formative feedback and also elicits idea diversity and improvable ideas, while students were learning about topics in primary science using group-drawing software and social networking. However, some caution is indicated in that social networking may degenerate into less productive social interaction in the absence of appropriate scaffolding to maintain productive teaching and learning scenarios (Madge et al. 2009).

The above literature suggests that one-to-one learning may be individual, collaborative, or community-based learning driven. A seamless learning scenario should encompass careful design and detailed definitions of conditions involving individual learning (i.e., the instructional design for learning individually and independently with HLDs), collaborative learning (i.e., the instructional design for learning collaboratively or cooperatively with HLDs), and community-based learning (i.e., the instructional design for learning in a community where intergroup communication and sharing are enabled and enhanced with HLDs). Because individual learning, collaborative learning, and community-based learning may play differing roles in the facilitation of learning, integration of different learning activities may deepen the effectiveness of each individual learning activity. For instance, integration of individual learning and community learning may promote a sense of ownership of learning in students. The following sections will address the difficulties faced in integrating these three types of learning activities and in structuring seamless learning scenarios for them.

Gaps in Individual, Reciprocal, and Community-Based Learning

The literature above demonstrates that HLDs have the potential to enhance learning engagement and performance in diverse types of learning scenarios. On the one hand, they could be used to enhance individual learning in contextualized environments, in particular the outside-classroom scenarios. On the other hand, the devices can also augment the reciprocal learning process to enhance social learning in the classroom, as each student can bring his/her own HLD to the classroom. However, to fulfill the goal of seamless learning, there are still several gaps between these learning scenarios.

Gaps Between Individual Learning and Collaborative Learning

The literature in the previous sections suggests that HLDs may facilitate social interaction in collaborative learning. In addition, using HLDs may facilitate the transition between the individual and collaborative group activities. Students can use the HLDs to perform individual learning tasks. Through the aid of wireless networks, they can apply the outcomes of what they have obtained during individual learning to the collaborative group activities. It is believed that the wireless communication capability of the HLDs can enhance the social interaction between students. However, HLDs are essentially designed for personal usage. For instance, PDAs were used extensively when they were announced in the commercial market. Such devices were originally designed to assist individuals in conducting simple cognitive tasks such as keeping personal calendars and note taking. The screens of PDAs also were small in order that they would satisfy the requirements of personal and mobile usage. Such a design might limit the social interaction required in reciprocal learning.

This limitation of HLDs in facilitating face-to-face collaborative learning was pointed out in the study by Liu and Kao (2007). They attempted to uncover the social interaction between students as mediated by the HLDs. The HLDs were used by students to conduct an individual problem-solving task followed by a group activity. During the group activity, the students were to generate group work based on individual work of each student – developed in the individual problem-solving activity. Their study found that student participation and interaction in the group activity may be hampered by the HLDs. This is because most students may focus only on the task on their own HLDs, ignoring interaction with others.

The ignorance of interactions may become even worse when HLDs are equipped with wireless communication capability and information-sharing applications. Figure 23.2 displays one of the results of their study, which shows the number of students participating in a four-student discussion group mediated by tablet computers. Each bar in the chart represents the number of students participating in discussion threads with wireless communications capability in an information-sharing application.

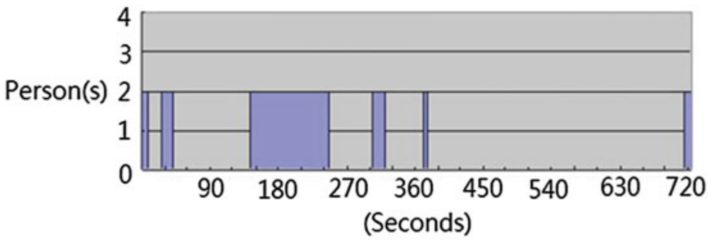

Fig. 23.2 Tallies of group members involved in interactions and their duration in seconds (Adopted from Liu et al. 2009)

It is obvious in the chart that interaction merely occurred among a small portion of the group. Therefore, simply applying HLDs in classrooms may lead to interaction problems such as fragmented communication patterns (Liu et al. 2009) and a decreased level of activity awareness (Scott et al. 2003) as students only concentrate on their own HLDs. A seamless learning scenario that integrates individual learning and collaborative learning does not naturally occur when students pull out their own HLDs and use them in classrooms.

The use of HLDs may not only interfere with student participation in group activities, it may also greatly impede the peer interaction pattern. Chung et al. (2012) analyzed peer interaction in a seamless learning scenario in which students used personal laptop computers to search the World Wide Web collaboratively on designated topics. This interaction pattern may have direct influence on the effectiveness of reciprocal learning. Only when students engage in a synergistic interaction pattern does group activity evoke higher-order thinking with students showing explicit or implicit responses to other group members (Schrire 2006). The analysis by Chung et al. (2012) involves diverse types of interaction cues including discourse records, hand pointing, visual focus, and works developed by the groups. They found that when HLDs were used, students tended to demonstrate distributed interaction patterns or unsocial interaction patterns.

Such interaction patterns showed direct influence on the group work. For instance, the mind map (see Fig. 23.3) developed by the students interacting with each other in an unsocial interaction pattern shows their search results and their reflections during the search process. However, in such an unsocial interaction, student search results and reflections did not lead to the generation of a solid argument. Therefore, the HLDs in classrooms did not necessarily improve peer interaction during collaborative learning activities. It required a sophisticated design to support a seamless learning scenario so that individual learning could be augmented by social learning activities through HLDs.

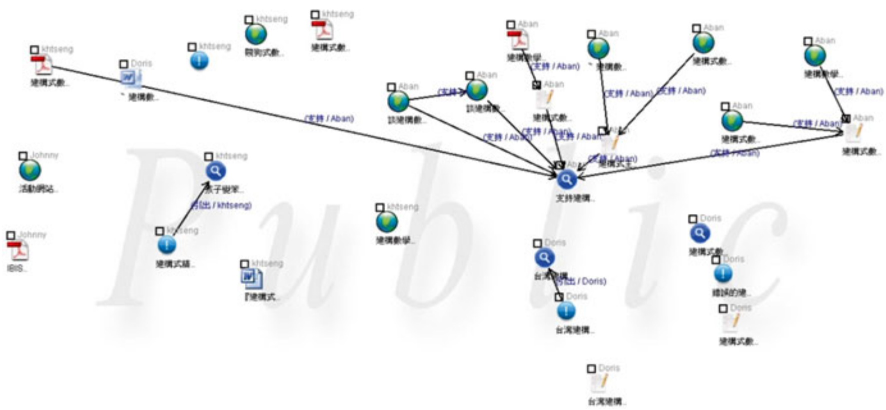

Fig. 23.3 The mind map developed by students using HLDs (Adopted from Chung et al. 2012)

To summarize, applying HLDs in the classroom without appropriately considering the affordances of the devices does not necessarily fulfill the goal of using these technologies. Furthermore, in the aforementioned studies, the learning performance was found to be impeded, and the students might have contrarily paid their attentions in learning as individuals, rather than learning with their peers (e.g., a decreased level of activity awareness, a fragmented communication patters, distributed and unsocial interaction patterns, etc.). Therefore, gaps between individual and collaborative learning are identified.

Gaps Between Individual/Collaborative and Community-Based Learning

HLDs enable individual students to participate in community-based learning at any place and time. More specifically, the HLDs may help students easily connect to social network sites and participate in the activities in the social network. For instance, current smartphones allow students to take photos and upload them to Facebook. Such a social network provides students with a platform on which to demonstrate their personal works and achievements so that they can experience the process of "learn to be an expert" (Brown and Adler 2008). The gap between the scenarios of utilizing HLDs with collaborative learning and community-based learning may be minimized due to that the HLDs are rather used as means for enhancing interactions in both collaborative and community-based learning. However, much literature indicates that the learning effectiveness of these social networks, in either collaborative or individual learning scenarios, is limited. This is because student participation in such a social network may be constrained to a rather superficial level. A survey by Irwin et al. (2012) found that only about half of the students consider Facebook to be an effective learning tool. Rambe (2012) analyzed student discussion on Facebook and concluded that "superficial learning also manifested in student failure to strategically harness Facebook discussions threads as information repositories for tracking the evolution of discussions".

In summary, although social networks may afford sociable media to support peer interaction, students seemed to perceive such social network platforms as having primarily a social function, but not an educational one (Madge et al. 2009). There is, therefore, still a gap we need to cross when using such social network platforms to facilitate a community-based learning experience.

Examples of Seamless Learning Across Multiple Scenarios

Thus, establishing a seamless learning environment that transforms learning from context to context, scenario to scenario, and location to location requires specific designs in the learning platform and activities. The following subsections demonstrate how these learning platforms and learning activities may be devised and organized to close those previously described gaps.

Bridging the Gap Between Individual Learning and Collaborative Learning

Researchers have attempted to facilitate a seamless learning scenario to connect individual and collaborative learning. Such facilitation can not necessary be accomplished with a single learning device. Instead, new learning environments, composed of multiple pieces of equipment, such as displays and classroom furniture, have been proposed to accommodate the use of HLDs in classrooms in ways that encourage the use and further development of individual learning outcomes in collaborative learning scenarios. One example of these new environments is to be found in the socio-technical classrooms designed by Liu and Kao (2007). Figure 23.4 displays the socio-technical classroom which supports one-to-one individual and collaborative learning. The socio-technical classroom is designed to support a seamless learning scenario that involves both individual and group learning activities. In particular, the design not only utilizes HLDs but incorporates also other diverse learning devices including projector screens and shared displays.

In the socio-technical classroom, the HLDs are mainly applied to support individual learning activities such as individual problem solving or answering questions. Furthermore, in order to integrate individual learning activities and the collaborative learning activities, it is necessary to bring individual learning results onto a shared learning space where groups of students can access and evaluate all of the group students' works. To address this issue, the socio-technical classroom is equipped with shared-display groupware which connects each HLD with a shared display during learning activities. With the shared display, students can upload and display their individual work from their HLDs. The shared display therefore plays an important role in facilitating group discussion, as all group members can refer to the

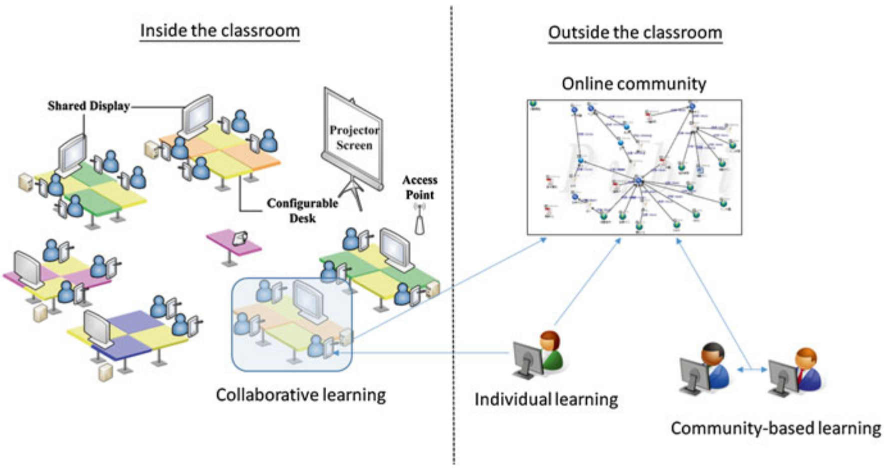

Fig. 23.4 The socio-technical classroom supporting one-to-one learning (Adopted from Liu et al. 2009)

individual work displayed for the group. Individual and group learning activities can thus be integrated to support a more sophisticated seamless learning scenario.

A series of studies have been conducted to understand the effectiveness of the design. Liu and Kao (2007) studied its effectiveness in supporting the Thinking-Pairing-Sharing (TPS) problem-solving scenario. The TPS activity integrated individual and group learning activities in which students used their own HLDs to solve a problem. They were then divided into groups and shared their solutions to the problems, during which they could upload their solutions to the shared displays, evaluate each other's solutions, and finally develop a shared solution. The sharing stage was facilitated by shared-display groupware. In such a scenario, communication and collaboration were not restricted to the HLDs, as students could also interact with each other through the shared display. All group members were attracted by such a large display and actively participated in the group discussion activity. Their interaction results as demonstrated in Fig. 23.5 show a different participation level than that in Fig. 23.2. When students used the HLDs along with the shared displays, they exhibited a higher participation ratio than they did in the environment without the shared display.

The socio-technical classroom scenario may be also applied to supporting diverse types of learning scenarios. Chung et al. (2012) proposed the use of shared displays to support collaborative Web discovery activities in which students jointly discovered knowledge by searching and using information on the Web. The collaborative Web discovery activities integrated individual and group learning by having students search for information on the Web individually and then jointly discuss their search results together. Chung et al. (2012) found that students tended to interact with each other in a peer-to-peer pattern when they used only HLDs (i.e., their laptop computers). In contrast, they found that students often focused jointly on and referred to the shared display when shared displays were used. They took part in the discussion at a deeper level to generate their own arguments. The results suggest that merely applying HLDs does not guarantee the seamless integration of different learning scenarios. Designs for educational environments have to consider the unique affordance of different devices to address the requirements of different learning scenarios.

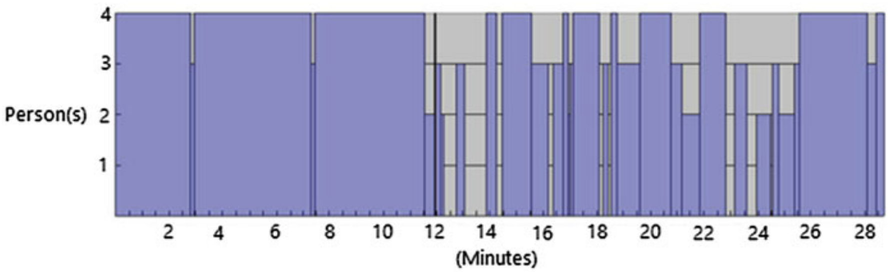

Fig. 23.5 Communication sequence diagram of the shared-display setting (Adapted from Liu and Kao 2007)

Bridging the Gap Between Community-Based Learning and Collaborative Learning

Liu et al. (2008) proposed an educational environment design that utilizes different devices for supporting seamless learning scenarios involving both community-based learning and collaborative learning. A model was proposed to mediate the continuous learning contexts and interface between the collaborative and community-based learning contexts, focusing particularly upon periods during which computers were unavailable to students. It has been suggested that temporal and spatial distance may retard the virtual collaboration progress and hinder the development of team cohesion (Prinz and Gross 2001). Use of HLDs, however, may well be critically important in these scenarios as they may enhance student awareness of online community-based learning activities when computer access to community-based learning platforms is not always available.

In order to bridge these inconvenient periods during which students may not have access to computers and to promote activity awareness among the members of the learning community, a message texting system was developed and integrated in a Web-based TGT groupware (i.e., Team-Game-Tournament) collaborative learning environment (Liu et al. 2008). This system used a simple GSM network to send text messages regarding each of the group members' learning activities to other members. Messaging features included assignment uploading, winning possibility assessment, suggestion posting, question posting, and annotating. While the learning activities were being conducted, each member's HLDs (i.e., mobile phones) received text messages regarding actions taken by their group members regarding their collaborative learning activities (see Fig. 23.6). As a result, it was found that students who had been assisted by the GSM messaging system demonstrated more collaborative action in their activities than did those who were not. Furthermore, students engaged in more team discussion and suggestion making in those instances in which the students' perceived engagement was also found to correlate with their work progress and achievement. Such real-time notification seemed to promote successfully student awareness of the course progress and to foster student commitment to the study groups. The results suggest that by integrating the online community-based learning platform and HLDs, individual and collaborative learning can be enhanced at the community-based learning level.

Conclusions and Future Direction

This chapter has implications for implementing portable personalized technology for education, especially in the handheld-enhanced learning scenario to construct a seamless environment for learning. First, this chapter identifies the 3-level HLD-enhanced learning scenarios to implement a seamless learning environment. Second, this chapter suggests certain learning activities to be arranged aside the 3-levels

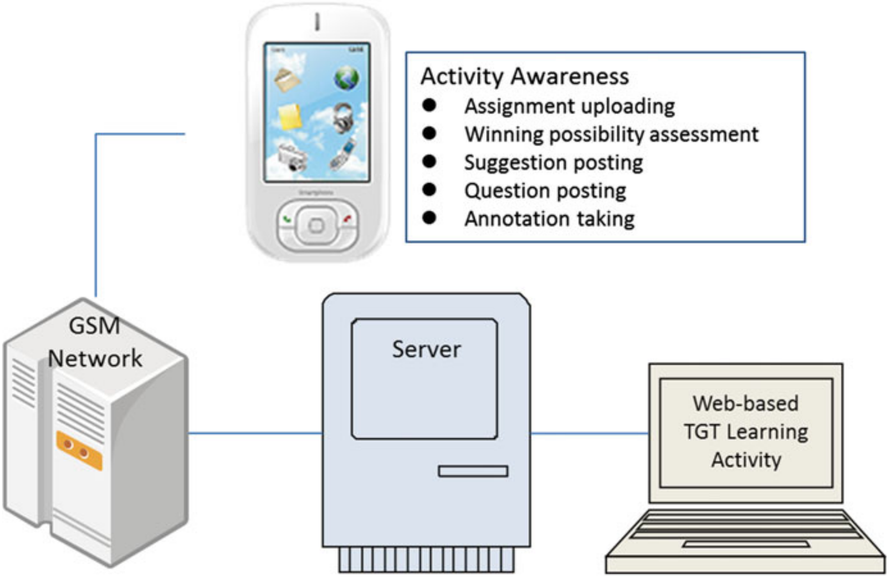

Fig. 23.6 Supporting activity awareness for Web-based collaborative learning with the GSM network (Revised from Liu et al. 2008)

HLD-enhanced learning scenarios. Third, the chapter identifies the advantages and difficulties on learning activities and instructional environmental settings. Lastly, this chapter suggests solutions to overcome those gaps between learning activities of different levels of HLD-enhanced learning scenarios.

Concluding Remarks

HLDs have been widely adopted in educational environments. Their use may be applied to transforming current teaching/learning practice into different educational scenarios. However, different devices may provide different affordances, and different learning scenarios may require different devices to achieve desired efficacy. It is thus quite difficult to apply one single learning device in support of seamless learning scenarios involving complex individual, collaborative, and community-based learning activities. Therefore, the design of educational environments should address the needs of different learning activities so that students may be thus able to transform what they have learned, smoothly and seamlessly, and to apply it to different learning activities.

The aforementioned literatures have demonstrated the use of different types of devices to support seamless learning scenarios. For instance, shared displays may be integrated together with HLDs to support the integration of individual and collaborative learning activities. Such a design may be helpful in promoting self-reflection, while students participate in a reciprocal learning process. The use of simple SMS notifications on mobile phones may bridge the gap between students and online social network sites and thus strengthen participation in community-based learning. Such applications of multiple HLDs may bridge the gap between different learning activities and aid in achieving the seamless learning objective.

By identifying the 3-levels HLD-enhanced learning scenarios/framework, there are advantages for education, such as providing suggestions for educators to construct a conceptually larger scope of learning environment within a certain disciplinary utilizing the seamless learning environment perspective. For example, an instructor may balance carefully the suggested 3-level HLD-enhanced learning activities accordingly for accommodating the needs of interaction and bring out the value of using HLDs; a language learning student may be benefited from not only getting exposed to her instructor, tutors, and classmates practicing and immersing in the classroom or the live online conferencing sessions but also staying connected and motivated through her HLD outside the classroom while the seamless learning activities are appropriate.

Future Works

Recent studies investigating the role which the HLDs play for building a seamless learning environment yield vastly in the higher education. Because students generally own their personal devices (e.g., HLDs), it may be easier and more freely to customize their personalized learning in their own pace. Thus, the application of the 3-level learning activities altogether may be beneficial in promoting learning in comparing to when applying only one level learning activity along in higher education. However, when utilizing inquiry-based learning for a certain instructional unit, students may search for and collect data in a contextualized field as an "individual learning activity" and exchange information and ideas in a "collaborative learning activity." This is because those individuals enabled by the HLDs can experience and record the authentic data, such as scientific exploration. When they are back to the classroom or the community online, discussion and collaboration can thus be facilitated from their findings. Therefore, such a 3-level learning activities may also be helpful to improve science learning in elementary schools. However, future works are still required to examine how different technologies may be integrated together to smoothly support the different types of activities in elementary schools.

Furthermore, more and more HLDs are equipped with capabilities to link to social network sites, wherein community-based learning may be enriched by the use of the new learning devices. However, how these social network sites can be integrated with formal learning activities is still not very clear. In particular, the commercial social network sites such as Facebook are designed primarily for social purposes. How HLDs can be integrated with social network sites to enhance learning still needs further investigation. In addition, the aforementioned socio-technical classroom includes different devices with different affordances to support learning, yet the analysis involves only activities taking place in a short period of time. How the design of the environment may influence the ecology of learning is also not clear, and it may be interesting and instructive to explore how a particular learning device such as the shared display may influence students' learning activities in a long term. Such further analyses may help in creating a clearer picture of how better to design and support a seamless learning environment.

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Chapter 24
Integrated Use of Multiple Social Software Tools and Face-to-Face Activities to Support Self-Regulated Learning: A Case Study in a Higher Education Context

Jari Laru and Sanna Järvelä

Abstract Recently, researchers have started to explore how mobile devices, social media or personal learning environments can support or promote self-regulated learning. In continuation of these research efforts, we developed a pedagogical framework for seamless learning based on the levels of interactivity and self-regulation of learning that different tools and activities enable. With this pedagogical design, we bridge individual and collaborative activities as well as face-to-face and mobile social media activities. The aim is to activate the degree of interaction and sharing desired and required for engaged learning. In this chapter, we introduce the theoretical principles of the framework: self-regulated learning, cognitive tools and macro-scripts. We also illustrate the pedagogical principles with a case study in a higher education context as an example of designing the integrated use of multiple social software tools and face-to-face activities to support self-regulated learning.

Introduction

The latest developments in information and communication technologies are changing the ways in which people communicate, collaborate and learn in fundamental ways (Lewis et al. 2010). Personal, portable and wirelessly networked technologies are becoming more prevalent in the lives of learners, while the development of social media has simultaneously led to new ideas about what it means to participate in educational activities (Liu and Milrad 2010). Multisilta and Milrad (2009) coined the term 'mobile social media' to describe the integration and interplay between these two emergent technologies. In its simplest form, mobile social media makes possible access to and situated updating of one's weblog. In other words, the use of mobile social media converts the students' acts into artefacts

J. Laru (✉) • S. Järvelä
Learning & Educational Technology Research Unit (LET), Faculty of Education, University of Oulu, Oulu, Finland
e-mail: jari.laru@oulu.fi; sanna.jarvela@oulu.fi

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(Roschelle and Pea 2002). At its best, mobile social media tools can be used for creating personalised-to-social learning activity (Wong et al. 2010), where mobile devices are used as an integral part of pedagogical design that consists of individual, collaborative and collective learning activities (Laru et al. 2012).

New affordances provided by the combination of mobile devices and social software tools lead us into a new phase in the evolution of technology-enhanced learning, one that forges new learning spaces and continuity between the pedagogical phases of the instructional design (Alvarez et al. 2011; Laru et al. 2012). In practice, the increasing use of mobile social media in education is stitching together the formal and informal learning contexts of learners and bridging individual and social learning, which is leading towards seamless learning. However, as noted in the review by L.-H. Wong and Looi (2011), most of the studies in seamless learning tend to discuss or analyse personalised and social learning separately or only focus on one of these aspects. The interplay between Web 2.0 tools and mobile technologies as well as the interplay between individual and collective activities is setting new challenges for supporting collaborative learning as teachers have to integrate these new technologies into more or less traditional learning methods, curricula and the everyday life of their schools (Arvaja et al. 2009). On a more general level, a major challenge in the technology-enhanced learning field is the overemphasis on designing tools and instructional activities for sharing and communicating, while the potential role of tools and appropriate instructional design for guiding and supporting learning processes has been virtually ignored (Järvelä and Hadwin 2013).

More recently, researchers have started to explore how mobile devices, social media or personal learning environments can support or promote self-regulated learning (Dabbagh and Kitsantas 2011; Kitsantas and Dabbagh 2011). In continuation of these research efforts, we developed a pedagogical framework for seamless learning based on the levels of interactivity and self-regulation of learning that different tools and activities enable. With the pedagogical design, we bridge individual and collaborative activities as well as face-to-face and mobile social media activities. The aim is to activate the degree of interaction and sharing desired and required for engaged learning (Järvelä and Renniger 2014, in press). In this chapter, we introduce the theoretical principles of the framework: self-regulated learning, cognitive tools and macroscripts. We also illustrate the pedagogical principles with a case study in a higher education context as an example of designing the integrated use of multiple social software tools and face-to-face activities to support self-regulated learning.

Self-Regulated Learning as the Theoretical Framework for Pedagogical Design

Our pedagogical design to seamless learning is grounded in the socio-cognitive perspective on learning and self-regulated learning theory. Self-regulated learning theory is concerned with how learners develop learning skills and use learning skills effectively, and it is guided by the environmental conditions that promote individuals to adopt, develop and refine strategies and monitor, evaluate, set goals, plan, adopt and change belief processes (Zimmerman and Schunk 2001). Self-regulated learning theory extends the conceptions of learning beyond cognitive processes and outcomes, acknowledging the interactive roles that motivation, emotion, metacognition and strategic behaviour play in successful learning. There is much research evidence that self-regulated learners are active participants who effectively control their own learning experiences in many ways, including organising and rehearsing the information that is to be learned and holding positive beliefs about their capabilities, the value of learning and the factors that influence learning (e.g. Schunk and Zimmerman 2012).

Recently, researchers have considered self-regulation as a social and collaborative learning context, and they have extended the conceptual perspective to the social aspects of self-regulation (Hadwin et al. 2011). Self-regulation occurs in independent, cooperative or collaborative tasks and leads to changes in the knowledge, beliefs and strategies individuals carry forward to new task contexts and changes in the structures and conditions of their environment (person n in Fig. 24.1). The ultimate goal is independence or personal adaptation in regulatory activity. Co-regulation occurs when the individuals' regulatory activities are supported, assisted, shaped or constrained by and with others. Regulatory support

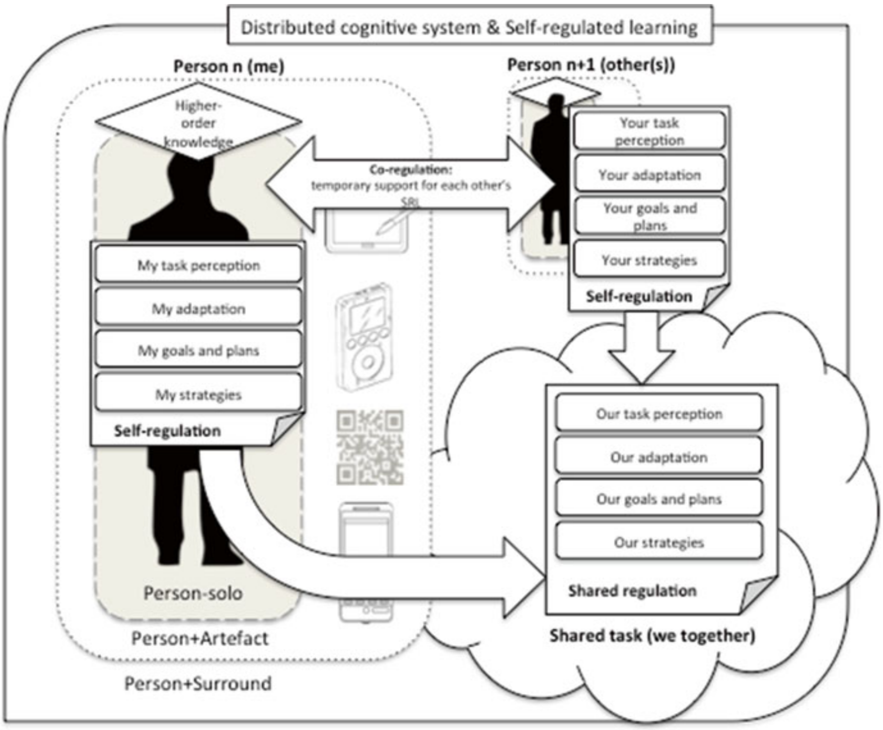

Fig. 24.1 Relationship between the distributed cognition system and self-regulated learning

may be distributed among group members, but the outcome of co-regulation is that each individual's regulatory activity is changed because of interactions with another (Volet et al. 2009) (person n + 1 in Fig. 24.1). Shared regulation occurs when groups regulate together as a collective, such as when they construct shared task perceptions or shared goals. When groups co-construct plans or align monitoring perceptions to establish a shared evaluation of progress, they are engaged in shared regulation. Therefore, socially shared regulation of learning refers to processes by which group members regulate their collective activity (shared task in Fig. 24.1). This type of regulation involves interdependent or collectively shared regulatory processes, beliefs and knowledge (e.g. strategies, monitoring, evaluation, goal setting, motivation, metacognitive decision making) orchestrated in the service of a co-constructed or shared outcome (Järvelä and Hadwin 2013).

Although the concept of seamless learning has been used to describe how technology can be used to stitch together the formal and informal learning contexts of the learners or bridge individual and social learning activities, it can be also used as the framework to bridge self-, co- or shared regulation with meaningful pedagogical activities. This chapter includes a full activity design, as suggested by L.-H. Wong and Looi (2011), with multiple phases (see Fig. 24.2); the mobile-mediated conceptualisation activity was just one phase of the instructional design. Products created in that phase can be characterised as artefacts that were used as a mediating tool for reflections, elaborations, reviews and knowledge building (Wong and Looi 2011).

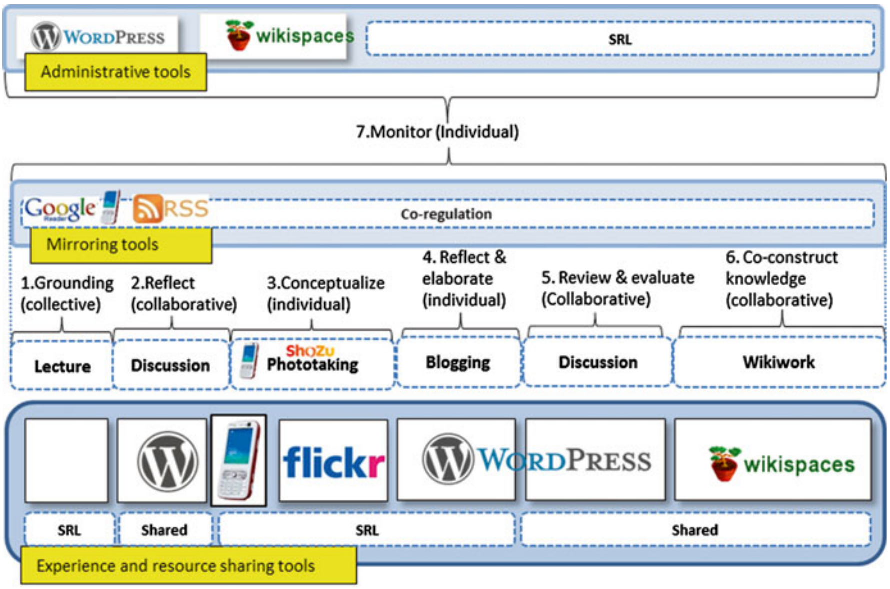

Fig. 24.2 Socio-technical design of the seamless learning case study

Technological Artefacts as Cognitive Tools for Supporting Self-Regulated Learning

The theoretical framework of this chapter is also based on the ideas of distributed cognition and cognitive tools. We build on the idea of distributed cognitive system (Perkins 1993) in which routine cognitive tasks are performed by tools (technological artefacts) and more complex communications and tasks are the core intellectual capabilities of people. By cognitive tools, we mean the 'smart tools' that we are using to mediate activities and augment our thinking processes (e.g. measuring or calculating) (Norman 1993; Pea 1993).

Until now, mobile devices have almost always been seen as merely devices for person-to-person communication (Nyiri 2002) or platforms for the dissemination of knowledge (Herrington et al. 2009). However, the newest mobile devices (e.g. smartphones, PDAs) have become versatile cognitive tools with rich educational possibilities (Laru 2012).

Contemporary smartphones, tablets and other mobile devices resemble the idea of Wireless Internet Learning Devices (Roschelle and Pea 2002), which are powerful, small and personal networked mobile devices. We are approaching the landscape of ubiquitous computing (Weiser 1991) where computers are embedded in our everyday activities, so that we unconsciously and effortlessly harness their digital abilities as effort-saving strategies for achieving the benefits of distributed intelligence (Pea and Maldonado 2006). With more generalised mobile devices with integrated functions, cognitive tools for doing things, like mapping concepts, running simulations, gathering data and structuring discussions, are appearing with novel technological affordances introduced by rapid technological advancements (Laru 2012). In sum, mobile devices have technological attributes that provide unique technological, social and pedagogical affordances (Kirschner et al. 2004).

In order to fit the role of mobile devices and applications into today's world of distributed cognition, an appropriate framework is needed. One approach for this is a distributed view of thinking and learning, as suggested originally by Perkins (1993). In his *person-plus-surround* conception, Perkins adopts a systemic view on cognition that goes beyond the individual actor: a system engaging in cognition usually consists of an individual (person-solo) and his immediate physical (person + artefact) and social (person + surround) surround. This surround (environment) might include tools, such as paper, personal computers and mobile devices (person + artefact), as well as other persons (person + surround) (see Fig. 24.1). This surround participates in cognition, not just as a source of input and as a receiver of output but also as a vehicle of thought. Nevertheless, the person-solo is the central actor in this model because transference of knowledge to an external tool (person+) is adequate if the tool only performs routine tasks that cost too much to internalise (e.g. some mathematical calculations). Higher-order knowledge (e.g. metacognitive knowledge), as opposed to knowledge about routine tasks, should reside in the person-solo or between multiple person-solos (or be internalised by the person-solo).

Figure 24.1 represents distributed cognitive systems where the learners' knowledge about regulatory processes is explicitly shown. In this figure, the learners' have personal or shared knowledge about how to monitor and control thinking, beliefs and strategies to reach a goal. Within the distributed cognitive system, cognitive tools act as a dynamic mediator of interaction between learners, their environment, other tools and information (Koole 2009). From the perspective of self-regulated learning, cognitive tools offer benefits for promoting socially shared regulation of learning by helping collaborators search for and organise information on their own and collaboratively and by prompting learners to metacognitively consider the features of their work across levels of self-, co- and shared regulation (Hadwin et al. 2011).

Adequate Scaffolds to Support Seamless Learning Activities

Generic cognitive tools, such as social software tools and mobile software, are building blocks of seamless learning designs. Such tools are progressively being used in educational contexts, but they are not usually specifically designed to help students engage in and gain skills in processes like problem solving, collaborative knowledge construction or inquiry learning. These tools rarely offer support with specific instructional guidance concerning collaboration and argumentation. Instead, generic cognitive tools (Kim and Reeves 2007) typically provide rather open problem spaces, where learners are left to their own devices. In such spaces, learners are free to choose (a) what activities to engage in with respect to the problem at hand and (b) how they want to perform those activities (Kollar et al. 2007).

Open learning spaces are an example of minimally structured learning environments where students may struggle to become engaged in productive collaborative interactions, such as questioning, explaining and justifying opinions and reasoning, elaborating and reflecting upon their knowledge (Kobbe et al. 2007). With respect to challenges in collaborative learning, Kollar et al. (2006) have distinguished two classes of scaffolds: (a) scaffolds that emphasise the activities of individuals by providing a higher degree of scaffolding using sentence openers, question prompts or detailed descriptions that may gradually be faded out as the learners become more competent and (b) scaffolds that set up conditions in which favourable activities and productive interaction should occur but leave the detailed aspects of interaction unconstrained. Especially in research on computer-supported collaborative learning (CSCL), such scaffolds have been called 'collaboration scripts' (the former have been referred to as 'micro-scripts' and the latter as 'macro-scripts') (Kobbe et al. 2007) which, in short, are structuring and orchestration tools for enhancing the probability that productive interactions occur in a group (Hämäläinen and Vähäsantanen 2011; Laru 2012).

Designing Self-Regulated Learning Activities by Using Macro-scripted Approach

According to Hämäläinen and Vähäsantanen (2010), research on scripting CSCL has concentrated on reviewing the connection between micro-scripts and individual learning (Weinberger et al. 2007), whereas much less is known about the effects of macro-scripts on collaboration within groups in authentic learning contexts. This chapter focuses on macro-scripts as a pedagogical method to facilitate group collaboration in authentic settings. In general, macro-scripts take a more pedagogical and top-down approach to collaboration (Kobbe et al. 2007). According to Häkkinen et al. (2010) and Dillenbourg and Tchounikine (2007), this approach to scripting collaboration is based on coarse-grained scripts that set up conditions under which desired activities and productive interactions between students should occur while leaving the details of the interaction unconstrained.

Macro-scripts are not restricted to either computer-based activities or collaborative activities in small groups; they can also include individual reflection (e.g. writing a personal weblog), which is required in order to transform experience into learning, and collective activities (e.g. conclusive discussion at class level), which are important phases for structuring the informal knowledge that emerges in individual or collective phases (Dillenbourg and Hong 2008). Dillenbourg and Hong have termed these scripts, which are neither purely computerised nor purely collaboratively, as 'integrated scripts'. Such scripts integrate several activities (e.g. read, summarise) across multiple places (classroom, field trip) and social planes (individual, collaborative, collective) within a single workflow (Dillenbourg and Hong 2008).

However, activities (e.g. argumentation) alone do not automatically produce high-level learning. Rather, learning is affected by the ability to build new and novel knowledge and the quality of the shared processes (Hämäläinen and Vähäsantanen 2010). While collaborative learning is often defined as a process of constructing and maintaining a shared understanding, the effects of group learning are more dependent on the effort exerted to develop a shared understanding despite differences among the group members.

According to Dillenbourg and Hong, macro-scripts are aimed at engineering and fine-tuning the frequency and quality of explanation, argumentation and mutual regulation that are necessary for students to develop a shared understanding. In other words, the design of a macro-script succeeds when it disturbs collaborative systems in such a way that interactions are necessary between participants in order to maintain or restore collaborative actions to gain the desired learning outcomes. Building on the ideas of macro-scripts and following the ideas of seamless learning, we have integrated the social mobile media and pedagogical design in terms of the level of interaction and collaboration and the level of self-, co- and shared regulation with meaningful pedagogical activities (See Table 24.1). For an indication of the different phases of instructional design for the case study (S1–S7), level of interaction (collective, collaborative or individual), the level of self-, co- or shared regulation and regulation activity are represented in Table 24.1.

Table 24.1 The pedagogical design principles for the case study

Phase	Interaction level	Learning activity	Regulation level (activity)
1	Collective	*Grounding [lecture] (weeks 1–3 and 6–8):* Each of the six, 1-week working periods started with a lecture in which students were grounded in main theoretical concepts. The specific themes were presented in the following order: (1) learning infrastructure, (2) learning communities, (3) metacognition, (4) self-regulated learning, (5) learning design and (6) social Web as a learning environment	*Self-regulated learning (planning and goal-setting)*
2	Collaborative	*Reflect [discussion] (weeks 1–3 and 6–8):* The purpose of this collaborative phase was to reflect on the lecture topic in groups and to formulate a problem to be solved based on the group members' shared interests during the following solo learning phases. The groups were advised to set their own learning objectives based on the topic and to write down these objectives in their personal blogs for further reflection	*Shared regulation (Reflection)*
3	Individual	*Conceptualise [photo-taking (or other visual representation)] (weeks 1–3 and 6–8):* In this solo phase, individual students were required to conceptualise their group members' shared interests (i.e. shared problem). In order to do so, they were required to identify and capture situated pictorial metaphors describing their shared interests. In practice, their tasks were to explore their everyday working and living environments and take photos with a camera phone	*Self-regulated learning (active learning and strategic activity)*
4	Individual	*Reflect and elaborate [blogging] (weeks 1–3 and 6–8):* The task of this phase was to further reflect and elaborate on photos in the students' personal blogs. First, they were required to analyse collected visual representations in order to discard ideas that were not relevant to their groups' shared learning objectives. Second, they were required to write blog entries about chosen photos in which they further elaborated upon the associations between the photos, the group-level objectives and the students' everyday situated practices. (Note: the students were able to see photos taken and blog entries written by other students and in other groups by monitoring their activities with an RSS reader)	*Self-regulated learning (evaluation and revising strategies)*

(continued)

Table 24.1 (continued)

Phase	Interaction level	Learning activity	Regulation level (activity)
5	Collaborative	*Review and evaluate [discussion] (weeks 4 and 9)*: The first task of this collaborative face-to-face activity was to review the group members' weblogs from the previous 3-week period. The second activity was to evaluate the usefulness of blog entries in the context of their shared learning objectives and to discard irrelevant ideas. The outcome of this phase was used as material for co-construction of knowledge in the groups' wikis	*Shared regulation (evaluation and revising)*
6	Collaborative	*Co-construct knowledge [wiki work] (weeks 4–12):* The task in this collaborative assignment was focused on integrating each group's chosen blog entries and visual representations into a cohesive and comprehensive product of all the course topics. In other words, the given goal was to formulate what they had learnt 'in their own words' and to produce it as uniform material that could be put to authentic use	*Shared regulation (active learning and strategic activity)*
7	Individual	*Monitor peer students' contributions [monitor]* (whole course): This was not an assignment per se, but it enabled the students to obtain different perspectives by seeing what others were doing with social software tools, and it helped students assimilate and accommodate their thinking. In practice, the monitoring activities were done by using cloud-based syndication tools (RSS)	*Co-regulation (evaluation)*

Case Study: Integrated Use of Multiple Social Software Tools and Face-to-Face Activities in a Higher Education Course

In order to illustrate the pedagogical design of seamless learning, a case study of small groups of learners (4–5 students in each group) was conducted using multiple social software tools and face-to-face activities in the context of higher education. The participants were 21 undergraduate students in a 5-year teacher education programme in Finland. All of the students were enrolled in a 12-week course entitled *Future Scenarios and Technologies in Learning* during the spring semester of 2009. The 21 participants included 16 females (76 %) and 5 males (24 %). The mobile phone-mediated activities in this course are an example of course-related activities outside of the normal class hours, such as artefact creation in daily life (largely incidental encounters or improvisations), which is another subtype of formal learning in informal settings.

The learners' core task was to integrate selected individual blog reflections and visual representations into coherent and a comprehensive wiki (see Table 24.1), which was also the main outcome of the learning activity.

The same content was elaborated upon multiple times when students encountered multiple representations of each of the six content topics using different analogues, examples and metaphors. In other words, the instructional design required students to revisit the same material, at different times, in rearranged contexts, for different purposes and from different conceptual perspectives (Spiro et al. 1991).

The socio-technical design of the case study consisted of recurrent individual and collective phases where students used multiple administrative, mirroring and experience and resource sharing tools to perform designed tasks and enable self-regulated learning activities (See Fig. 24.2) (Laru et al. 2009, 2012).

Firstly, a course blog and wiki were the administrative tools used in this study, which aimed to support the students' self-monitoring and self-evaluation efforts (Kitsantas and Dabbagh 2011). Secondly, a simple syndicate (RSS) tools, FeedBlendr and FeedBurner, were used to create individual, group and class-level feeds from students' Flickr, WordPress and Wikispaces accounts. These activity streams were available for all students via Google Reader and visible as RSS widgets in a sidebar of the respective blog or wiki. This enabled the students to bind social software tools together and they may be seen as additional collaborative tools that facilitated the relationships between different task phases, the students, the content they produced and the tools they used in this study (Lee et al. 2008). From the perspective of self-regulated learning, RSS syndication was used as a co-regulated learning tool because it enabled the students to monitor the individual, group and class-level activities of other students. It targeted group awareness, such as what other students were doing in their individual and shared learning tools (experience and resource sharing tools in the Fig. 24.2) (e.g. Leinonen et al. 2005).

Thirdly, multiple experience and resource sharing tools, as well as face-to-face phases, were used to support individual and shared self-regulated learning activities (Järvelä et al. 2007; Kitsantas and Dabbagh 2011; Laru et al. 2012). In the discussion phase immediately after the lecture, small groups of students regulated as collective when they had constructed shared task perceptions and shared task goals for the next phase (see conceptualisation, Phase 3). In the third phase, students used a personal mobile multimedia computer, which was integrated with features including a 3.2 megapixel digital camera, 3G connectivity and an Internet browser in order to identify and capture the situated pictorial metaphors describing their group's shared interests. The task of the fourth phase was to further reflect and elaborate on photos taken by using a Wordpress weblog, which captured the student's reflections chronologically, enabling self-monitoring and self-reflection. Both of these individual phases were designed so that each group member in the small groups of students had to take responsibility for setting individual goals and standards for his/her own contribution to the team (Järvelä and Hadwin 2013). In the fifth phase, blog articles and pictorial representations were discussed when the student groups collectively constructed their shared task perceptions by evaluating the usefulness of the blog entries in the context of their shared learning objectives. The outcome of this phase was used as material for co-construction of knowledge in the groups' wikis. In the sixth phase, wiki was used as a vehicle for integrating and elaborating upon individual blog entries, which has been seen as an important task strategy for self-regulated learning (Hazari et al. 2009).

Conclusions

Pedagogically grounded instructional design is needed in order to effectively use emergent technologies. The employment of mobile devices, including mobile phones and tablets, is a growing trend in education. This practice has been widely technology driven and often justified simply by the importance of using new technology in the classroom. Since we are currently living between the stages of mobile social learning and a ubiquitous future, the role of mobile technologies in different learning contexts is still a challenge for researchers and practitioners. Our claim is that seamless learning can be one productive way for schools and other educational institutions to promote learning skills, namely, self-regulated learning and collaboration, and to prepare people for the twenty-first century learning society. To advance research on self-regulated seamless learning, we propose a few design guidelines for self-regulated seamless learning.

We share the constructivist belief that students should learn in environments that deal with *'fuzzy', ill-structured problems*. Designing challenging collaborative learning tasks provides students with an opportunity for engaging in multiple strategic activities and opportunities for self-regulation and the shared regulation of learning. There should not be one right way to reach a conclusion, and each solution should bring a new set of problems. These complex problems and challenging learning tasks should be embedded in authentic tasks and activities, the kinds of situations that students would face as they apply what they are learning to the real world (Needles and Knapp 1994). Challenging learning tasks need scaffolds and support. For example, Belland (2011) has suggested the following guidelines for the creation of appropriate scaffolds: (a) support problem reformulation through qualitative problem modelling, (b) do not give specific end goals, (c) enable students to make comparisons between cases, and (d) enable students to work collaboratively.

As suggested by Spiro et al. (1991), the same content can be *elaborated multiple times*. In practice, this means that students encounter multiple representations of content using different analogues, examples and metaphors, for example, by using mobile tools or social software. Towards that end, the required instructional design is one that enables the students to revisit the same material, at different times, in rearranged contexts, for different purposes and from different conceptual perspectives. The same content can be also elaborated upon with multiple individual and collaborative phases before the collective activity allowing students the opportunities for self-, co- and shared regulatory processes (Järvelä and Hadwin 2013).

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Afterword

As an evolving area of research and practice, the future of seamless learning will continue to be shaped and reshaped by the academics, the practitioners, and perhaps the industry. Some authors of the chapters in this volume have kindly contributed their personal insights on the new directions of seamless learning. In this section, individual and group opinions are presented in alphabetical order of presenting author(s) without any reviewer or editorial intervention. In turn, we hope to lay out diversified perspectives for readers to evaluate and perhaps be inspired for their studies of the compelling world of seamless learning.

Ben Bachmair and Norbert Pachler

Modes of instruction such as teacher-guided approaches, technology-enhanced situated learning or, indeed, seamless learning are in danger of being ideologically exploited. Actually learning is at risk of becoming a feature of self-optimization in the context of a continuously changing labor market: to take personal responsibility and to learn at all times to reach pre-defined assessment objectives.

A prerequisite for an understanding of learning as self-optimization is a definition of learning and its results as resources. This redefinition has become an economic reality which finds expression in notions such as the global knowledge society. The PISA tests, used widely around the world, deliver the standardized data and generate comparable knowledge as a reusable resource. On the other hand, the ideological orientation of traditional and teacher-guided instruction may impact as a potential source of inequality depending on learners' social background.

One way of addressing the inherent ideological risks of teaching traditions and learning innovations is to conceptualize learning and its outcomes explicitly as resources. There already exists a critical frame around resources which is derived

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from ecology and which we adapt to learning by means of a cultural ecology. Even though there is no educational CLUB OF ROME, it can be argued that education needs a cultural ecological framework which reflects the impact of institutionalized learning modes on the development of human beings. From such a perspective, the development of humans is the key indicator of learning rather than standardized testing and assessment results.

Dan Kohen-Vacs and Miky Ronen

In recent years, educators make efforts to exploit real-life situations as educational opportunities incorporated in their pedagogical strategies. Outdoor learning poses new challenges for teachers requiring them to orchestrate learning in an open and uncontrolled environed. Outdoor learning critically depends on the teacher and students' ability to access information from anywhere at any time, to share it, and finally to conduct educational discussions related to this information.

Mobile technology and its recent availability to all provided teachers with new opportunities to conduct major part of their pedagogical strategies beyond the boundaries of the traditional environment used for educational purposes. Mobile technologies also offer teachers and students a convenient mean for conducting their educational transactions in such settings across contexts.

Pedagogical strategies supported by mobile technologies should be accounted while designing a multiphase and cross context pedagogical strategies. Such strategies could be combined with authentic situations and challenges that aim to provide better preparation of students to their real life. Therefore, we see that our contribution would focus in providing efficient means, strategies, and tools enabling teachers to take advantage of the well-assimilated technology.

Agnes Kukulska-Hulme

Inspired by a positive word such as “seamless,” we can work with enthusiasm in a common cause, yet such words can also be a little dangerous. Not all learning that is seamless is instantly good or right. Not all learning that is “flexible,” “personalized,” “social,” or “adaptive” (add your own favorite word here!) is necessarily worth developing and promoting. We must not forget to engage our critical mind. Rapid advancements in technology are accompanied by explosions of creative and exuberant uses of language, ingenious borrowings, and extensions of meanings. Such language evolution can energize, yet it can also create illusions or lead to unintended results. Seamless learning will generate new vocabularies as words are repurposed and new ones created or adopted from other fields. Mobile and ubiquitous technologies may help track this continuous evolution and will be instrumental in accelerating change. Future research and practice should deliberately reflect on the influence of language in the technologically mediated processes of developing and appropriating new varieties and modes of learning.

Jari Laru and Sanna Järvelä

When progressing the idea of seamless learning, researchers have started to explore how mobile devices, social media, or personal learning environments can support or promote self (SRL) and socially shared regulated learning (SSRL).

Tools provided by the current technology can be used for supporting twenty-first-century learning skills. This is, learner's regulatory activities are prompted with others (co-regulation) or helping to negotiate shared task perceptions, goals, and strategies (socially shared regulation). Currently, researchers agree that self- and socially regulated learning processes are contextualized to the learning situation, and besides, individual characteristics, the role of the learning context, and task type and support should be taken into account.

From the point of seamless learning, more theoretical and empirical studies are needed to gain better understanding about how to design for learning, because there are only few studies where both socially shared regulated learning and seamless learning have been empirically explored.

Susanna Nordmark and Marcelo Milrad

The wide adoption of mobile and ubiquitous technologies combined with access to content in a wide variety of settings allows learners to experience new learning situations beyond the classroom. Seamless learning can enable a continuous learning experience across different settings, such as home-school or workplace-college. Despite the many research efforts conducted in the field, few are those that have succeed integrating mobile devices to promote innovative and sustainable pedagogical practices and that have resulted in the implementation of useful learning tools widely used by teachers and students.

For educational innovations to be sustainable, it is crucial that teachers start to embrace and adopt both the theories and technologies in a manner that makes the experiences and outcomes from each effort survive, bloom, and develop. By doing so, teachers could see measurable impacts that may improve the quality of their educational practices. Therefore, all issues related to the teachers' adoption and perceived use of technology are essential for sustainability and scalability aspects in seamless learning initiatives. Hence, one major challenge for the mobile and seamless learning community is to rethink not only the fine-tuning of the technological and methodological approaches introduced in the different projects but to put a heavy focus on how to further elaborate and enhance the overall features of inspiration, motivation, and adoption from the teachers' point of view.

Hiroaki Ogata, Noriko Uosaki, Mengmeng Li, Bin Hou, and Kousuke Mouri

We have a dream that one day all we have learned in our lives will be recorded into computers using life-log technology. Also, we have a dream that one day learning which happened in the past will be seamlessly connected to the ones in the future. Then, how will human learning processes and classroom learning will be changed in this context?

Li Sha

In addition to everlasting development and application of advanced technologies and advices to mobile seamless learning (MSL), more theoretical and empirical studies are needed to uncover key personal (e.g., motivation, metacognition) and contextual factors (e.g., pedagogical conditions, family support) for effective MSL. It is also necessary to explore how effective MSL can cultivate K-12 students' self-regulatory and collaborative skills for their lifelong learning in the twenty-first century. As a result, a big challenge facing MSL researchers is how to enable researchers, teachers, and students to formatively assess self-regulated and collaborative learning as on-the-fly events while students engage in seamless learning across various settings (e.g., in school, out of school).

Mike Sharples

Continuity and context have become the two central themes for understanding learning in a mobile world. We interpret the world as a flow of experience. Mobile devices can assist in creating successful flows of conversation and knowledge across time and location. Countering this experiential flow, we feel connected to times and places that are familiar or important. Situating learning in context enriches the experience and helps us to recall its purpose and outcomes. The challenge, then, for educators and developers of mobile learning is to enable a seamless continuity of learning while also linking that to significant settings as contexts for learning. For example, as a visitor to a city, I may want to plan my trip in advance, deciding on places to visit and learn about; then I experience a delightful flow of holiday activities enriched by my planned itinerary; and then after the holiday, I revisit that trip and its locations, enhanced with multimedia city guides and my own photos. Continuity and context fit together to enable seamless learning.

Hyo-Jeong So, Esther Tan, Yu Wei, and Xujuan Zhang

What is seamless learning and why the need to design for seamless learning no longer warrants further debates. Greater connectivity and a growing participatory culture powered by technological advances drive the global need to stay relevant in the changing educational scenes. However, it is needful to recognize that technological affordances can only play but a mediating role. It is not an end in itself. The centerpiece in the design process is to scaffold and to support seamless flow of learning across contexts. Focus should be given to the learning process and conditions whereby learners are engaged in creating meaningful contexts and content through the mediation of mobile technologies and collaborative meaning-making practices. Next, the "know-how" and "when" in the implementation of seamless learning is an equally daunting task. A structural change at the institutional level on curricula, goals, and assessment is a critical issue for consideration. This also implies a need for professional development for teachers as effective agents in facilitating and scaffolding greater student autonomy in self-directed learning. Any future research undertaking on seamless learning should still seek to address the fundamental question words—"what," "why," "how," "when," and "for whom"—simply because technological infrastructure support and schools', teachers', and students' readiness vary from context to context. These are critical and pragmatic issues, which shall, to a large measure, determine the success of creating and sustaining seamless learning spaces.

Yanjie Song and Siu Cheung Kong

Future research may lay emphasis on investigating into viable and novel methodological approaches that address the issue of how to capture students' learning process and outcomes in the fast-changing, reconstructed contexts. Some scholars propose using mobile devices for contextually and repeatedly sampling students' knowledge practices in their natural context to examine students' intellectual and emotional processes at personal and collective levels. This is related to the trialogical approach which emphasizes collaborative development of mediating objects or artifacts students' worked on rather than monologues within mind (the acquisition view) or dialogues between minds (the participation view); it also concerns how to address the "big data" produced by the students in the learning process. By doing so, we can understand better how students construct and advance their knowledge in seamless learning environments and identify potential issues for pedagogical decision making. Thus, important implications can be uncovered in seamless pedagogical practices.

Marcus Specht

The Oxford Dictionary defines seamless as "with no apparent gaps or spaces between one part and the next." This book gives a variety of definitions of seamless learning and the gaps that can be identified and can be bridged or blurred. From my personal point of view, seamless experiences of humans can develop in two different ways. On the one hand, humans learn to handle artifacts in their environment in an outstanding professional or artistic way, i.e., like learning to play an instrument. While the experience at the beginning feels uncomfortable and difficult to achieve, playing the instrument becomes more and more fluent with practice and experience, and for the master, the instrument can feel as a natural extension of his/her body. In such mastery, improvisations can express individual emotions, tell stories, or even create dialogue in an artistic improvisation with others. On the other hand, new technologies enable new forms of interaction, creation, and learning. To stick with the metaphor of artifacts or musical instruments, researchers and designers of technology-enhanced seamless learning create new instruments with which so far unheard music can be played. In this case, the starting point of seamless learning experiences is the linkage of isolated experiences with the help of new technologies as described in the foreword by Chan (this book). New technologies enable the augmentation of human senses and the expansion of human expressiveness and hopefully human interaction and therefore human learning. To research how to create these seamless learning experiences and the technology that enable these is a main goal of this book, and the authors are thankful for all their rich contributions.

Mike Tissenbaum and James D. Slotta

Through the use of increasingly powerful, affordable, and mobile computing devices, students are finding new opportunities to connect their experiences at home, in their neighborhoods, on fieldtrips, or other informal learning spaces (e.g., museums or science centers) to their traditional classroom settings. As the opportunities for learning become more diverse, so too are the perspectives students may bring to their learning. A student's experience outside the classroom is far more unique and differentiated than what is encountered in the classroom. Similarly, students engaging in inquiry on field trips (e.g., to a local stream or watershed) will have differing perspectives, depending on what they may encounter there, individually or in small groups.

The challenge for educational designers becomes how to develop tools that allow students to make personally relevant contributions from one context (e.g., the field trip) that are meaningful to their work in another. Another important challenge is that of making student contributions relevant to a wider community of peers—connecting, aggregating, and visualizing these contributions in ways that support the educational goals of the community.

This approach requires us to think of the community's intelligence as being distributed across the various contexts in which students learn and as embedded within the various tools and media that support their individual, collective, and collaborative interactions. In order to support this distributed notion of learning, we must develop tools and materials that allow students to seamlessly traverse the various boundaries between contexts, tools, and environments, to help them create a shared understanding within the community, and to apply community knowledge in whatever context they find themselves.

The use of aggregate visualizations, intelligent software agents, and data mining shows considerable promise in supporting such a distributed view of knowledge communities. Coupled with real-time messaging systems, such technologies can respond to a learner's current contexts, presenting materials collected across multiple contexts in ways that support the current pedagogical goals. The development of such technology frameworks for learning will become increasingly important to support the next generation of knowledge workers and respond to the changing nature of education.

Lung-Hsiang Wong

Seamless learning should eventually become a learning approach, disposition, and even theory at its own right (rather than a special form of mobile learning), to join the rank of more established learning notions such as inquiry learning, situated learning, self-regulated learning, cooperative and collaborative learning, etc., which can be substantially enhanced by modern technology. Therefore, while the learning technologists may continue to push the boundary of the mobile, ubiquitous, cloud computing, and adaptive technologies to transform the learning ecology toward the direction that is more conducive for individual- and community-based seamless learning practices, others would venture into an anthropocentric approach of seamless learning research in which learners occupy a central position and the technology is positioned in relation to them. To accomplish this end, it takes more scholars to further unpack and theorize the salient characteristic of seamless learning, namely, *bridging* one's learning efforts across multiple settings, in both cognitive and sociocultural lenses.

Shenquan Yu and Xianmin Yang

The organization of learning resources is a fundamental factor of ubiquitous learning environments. Ubiquitous learning needs adaptive and contextual learning resources, which should exist in real time, reflect the latest developments in related areas, and meet learners' actual real-time needs. How to implement the continuous generation and evolution of digital resources is critical for ubiquitous learning. The research of resource evolution has significant implications for the development and implementation of u-learning.

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Index

1:1, 5, 10, 20, 29, 144

A
Adaptive learning resources, 142
Adaptive systems, 132
Advanced distributed learning (ADL), 379
Affordance networks, 77, 78
Affordances, 77
After-school schools, viii
The AICHE model, 123–137
  four layers of, 125–127
  synchronization process, 127–128
AMULETS, 185
Analytic SRL model of mobile seamless learning, 102–104
ARLearn framework, 133–135, 392
ARLearn platform, 401
Artifact-oriented analysis, 28, 300
Augmented reality, 63, 135–136
Autonomous learning, 13
Autotelic/self-motivating learning, 42

B
Badges, 402
Beyond information given (BIG) question, 338
Big data revolution, xii
Blended Mobile Learning Model, 322–331
Bridging, 10, 300
  across locations, 9, 28, 47, 50, 187, 233, 444
  across time, 16, 187
  collaborative learning and community-based learning, 465
  combined use of digital and non-digital learning resources, 28, 264
  combined use of multiple devices, 8, 187, 278, 444, 447
  formal and informal learning, viii, 4, 18, 42, 48, 60, 72, 117, 135, 162–163, 168, 172–173, 186, 253, 267, 271, 275, 281–291, 363, 427
  formal learning and practice, 389–391
  individual and social learning, 11, 93, 135, 155, 186–187, 237, 253, 453–468
  knowledge synthesis, 20, 168–169, 188
  learning and assessing, xii
  multiple information channels, 124
  multiple learning tasks, 187–188
  physical and digital realms, 187
  self-regulation, co-regulation and shared regulation, 476–481
  student-generated artifacts to mediate subsequent learning, 16, 28, 188, 237–238
  supporting learning activities across multiple contexts, 130–131
Bring your own device (BYOD), 79, 384
Busuu, 288

C
CeLS. *See* Collaborative e-learning structures (CeLS)
Chinatown 2.0., 16
1:1 Classroom campaign, viii
Cloud computing, xii, 29, 30, 47, 144
Cognitive apprenticeship, 182
Cognitive tools, 110

L.-H. Wong et al. (eds.), *Seamless Learning in the Age of Mobile Connectivity*,
DOI 10.1007/978-981-287-113-8

Collaborative e-learning structures (CeLS), 443
Collaborative tagging, 446
Combat medic, 113–114
Community-based learning, 456, 458–459
Computer supported collaborative learning (CSCL), 442
Connected learning, 47–49
Context(s), 13, 41–53, 59–61, 64, 65, 116, 272–273, 345
Context aware, 6, 62–65, 122, 124, 148, 159, 165
Co-regulation, 474
CSCL. *See* Computer supported collaborative learning (CSCL)
CSCL scripts, 439–450
Curriculum mobilization cycle, 21
  design principles, 421

D
DCog. *See* Distributed cognition (DCog)
Degree of structuredness, 345
Design-based research (DBR), 231, 310, 337, 342, 360, 399, 420
Design ethnography, 27
Designing for change, 336
Designing for emergent learning, 422–429
Dewey's philosophy of continuity, 4
Distributed cognition (DCog), 11, 13, 14, 27, 77, 475–476
Distributed cognitive system, 476

E
Ecology of resources (EoR), 124, 127
Education cloud services, 148
EduCity, viii
Eduinnova system, 50
Effectivities, 77–78
Effectivity sets, 77–78
Elmo project, 45
Emerging learning objects (ELO), 442–443
Enculturation, 301
EoR. *See* Ecology of resources (EoR)
Experiential learning, 11
External representations (ER), 14

F
Facilitated seamless learning (FSL) framework, 18, 22, 301, 313
Flipped classrooms, 44
Flow of learning, 42–43
Flow state, 43
Future Classroom, viii

G
Game-based learning, xii, 44
  learning game, 397–415
G1:1 community, vi–vii, 5, 16
  G1:1 network, 268
Geo-collaborative Application, 188–194
Geographic Information Systems (GIS), 183
Geo-localization, 183–186
Growing Up, 309

I
Incidental learning framework, 288–289
Information channels, 124–137
Inquiry-based learning, 48, 51, 79, 134
Inquiry-based science teaching (IBST), 26
Intelligent Agents, 226–255
Intentional learning experiences, 338
Interaction bandwidth, xii

J
Judgments of learning (JOLs), 98, 99

K
Knowledge building, 61
Knowledge building practices, 337
Knowledge Community and Inquiry (KCI) model, 228
Knowledge creation space, 336

L
Learner autonomy, 283
Learner-centric seamless learning, 285
Learning cells, 143–157
  concept, 143
  core features, 145–149
  runtime environment, 149–151
  system development, 151–155
Learning hub, 20, 29–30
Learning object, 145
Learning trails, 9, 16, 323–331, 337–350
  application description, 194–196
  definition, 336
  three categories of task types, 346
Learning with patterns, 194–196
Life-log, 161
Lifelong learning, 92, 94, 102
Linking of RFID and movie system (LORAMS), 160
LOCH, 185, 309
Log-Organize-Recall-Evaluate (LORE), 164–165

M
MASELTOV project, 288–290
mDS workflow, 358–374
Meaning making, 16, 59, 187
  collaborative, 336
Mediation by artifacts, 28
Metacognition, 97–98
Micromandarin, 186
Micro-scripts, 477–479
Mindergie, 397–415
Mobile devices
  as cognitive tools, 20, 98, 100, 475–476
  as cultural resources, 59
  as metacognitive tools, 98, 100
  as representational resources within or across contexts, 60
Mobile digital storytelling (mDS), 353–374
Mobile learning
  grand challenges for mobile learning research (MLR), 385–388
Mobile Learning Object Deployment and Utilisation Framework (MoLODUF), 203–221
  the twelve dimensions of, 204–208
MobileMath, 185
Mobile serious games, 133
Mobile social media, 471
Model of the pedagogical considerations of seamless learning, 274
Moop, 185
Move, Idioms, 23, 309
Multimodality, 357
Multimodal texts, 357
Multiple learning pathways
  multiple pathways, 422
Museum visits, 48
MyArtSpace, 48
MyCLOUD, 23, 310–314
My sports pulse, 110–112

N
Niches, 78–89
Novelty space, 343, 349
nQuire, 51

O
One-to-one, v, vi, 268
Open, distance and eLearning (ODeL), 202
Orchestration of learning, 49–52, 223–255

P
Pedagogical scripts, 225
Peer scaffolding, 313
The Personal inquiry project, 48, 53
Person-plus-surround, 475
Physics Learning Across Contexts and Environments (PLACE), 231–243
  PLACE.neo, 237–238
  PLACE.web, 233–237

R
Recontextualization, 111
Repairing mechanism, 340
Resource organization, 142–157
Ride and drive, 112

S
SAIL Smart Space (S3), 229–255
Scaffolding, 26, 80, 124, 185, 204, 238, 243, 249, 275, 324
  question and scaffolds, 339
  scaffold, 425, 476
SCROLL, 309. *See* System for Capturing and Reminding of Learning Log (SCROLL)
SDT. *See* Self-determination theory (SDT)
Seamless connections, 267
Seamless culture learning, 325–327
  history of the city square, 185
Seamless flow of control, 52
Seamless geography learning, 194
Seamless history learning
  first mDS pilot study, 360–374
  mobile learning trail, 339
  My Village, 444
  River Mystery Trail, 340
Seamless language learning (SLL), 185, 271, 295–314
  language as a bridge connecting formal and informal learning, 281–291
  link rate in vocabulary learning, 169–170
  literature review, 304–310
Seamless language learning (SLL) framework, The, 295–314
  the design principles, 301–304
Seamless learning
  adaptability, 271
  adaptivity and adaptability, 32, 148
  conceptual groundings, 10–14
  curriculum and learning design, 21–27, 225, 278, 419–434
  definition, v, 10, 41, 161, 455
  metacognition, 93
  methodological issues, 27–28, 100–102

motivation, 42, 100, 273
parental involvement, xi
questionnaire, 18
researchers' perceptions on mobile-assisted seamless learning, 6, 8–10
scaling-up, 431–434
the scoping descriptions of mobile-assisted seamless learning, 7
sociocultural perspective, 14, 301
systemic change, 4
teacher readiness, 433
technology as 'enabler' or 'enhancer,' 32
three key elements of, 261
Seamless learning contexts, 336
Seamless math learning, 185
Seamless medical learning, 115
Seamlessness, xiii, 262–263, 275
definition, 267
SEAMLESS project, 22, 23
Seamless rate, 162–163
Seamless science learning, 26, 48, 65, 79, 422
physics in their everyday lives, 231–233
Seamless security and defense learning
security and defense, 377–395
Seamless STEM learning, 110
Seamless workplace learning, 112, 113
workplace, 397–415
SECI model, 13
Second language acquisition (SLA), 297–300
Self-determination theory (SDT), 97
Self-directed learning, 422, 427
Self-regulated learning (SRL), 92–104, 133, 471
Self-regulation as agency, 94–95, 102
Semantic-based aggregation model, 145
Sensors, 131–133
Shared regulation, 474
Situated learning, 61, 64, 65, 182–186
requirements, 185
SketchMap, 186
SLA. *See* Second language acquisition (SLA)
SLL. *See* Seamless language learning (SLL)
SMALL, 309
Social cognitive networks, 142, 147
Social cognitive theory, 95–96
Social interaction, 182
Socio-technical classrooms, 463–464
Spaces, 7, 11, 18, 59
SRL. *See* Self-regulated learning (SRL)
System for Capturing and Reminding of Learning Log (SCROLL), 159–177
user interface, 165–167

T

Tagging, 165, 232, 237–238
Task-based [language] learning (TBL), 297–300
10 Dimensions of Mobile-assisted Seamless Learning (10D-MSL), 17, 23, 32, 116, 197–198, 300, 302, 323–331, 440
MSL dimensions, 450
seamless learning in situated learning, 186–188
10 characteristics delineating, 269
ten different dimensions characterizing activities for MSL, 355
ten overarching features/dimensions of MSL, 385–388
Transformation of participation, 27

U

Ubiquitous learning, 6, 7, 264–267
Ubiquitous learning log object (ULLO), 160, 164
Ubiquity, 58, 94, 264–265
ULa Lab, 309

V

Virtual companions, xii, vii, xii, vii
Virtual family, 115–116
Vocab Challenge, 309

W

WE Learn, 22, 309
weSPOT project, 134
Wireless internet learning devices (WILD), 475

Z

Zombie Division, 44
Zones of Proximal Development (ZPD), 204