USING ITERATIVE DESIGN AND DEVELOPMENT FOR MOBILE LEARNING SYSTEMS IN SCHOOL PROJECTS

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ABSTRACT

Different approaches have been proposed on the use of digital and interactive technology in mobile learning contexts. In line with recent findings in the literature, we suggest that mobile learning systems benefit from an iterative design and development process within a holistic, socio-technical system view. This system view makes allowance for the complex dynamics between teachers, students, researchers, the multiplicity of contextual factors, and the specifications and requirements of the digital devices and applications, as well as their interrelations. Iterative design and development incorporates evaluation results of mobile learning scenarios that were designed according to system-based analyses. The school projects described in this paper, as well as their evaluation results, served as an integral part in creating a dynamic optimization process for the design and development of digital and interactive systems for mobile learning contexts in primary and secondary schools.

KEYWORDS

Mobile learning, schools, iterative design, evaluation, digital and interactive devices.

1. INTRODUCTION

Mobile learning has become a major topic for the learning research community within the last 10 years. The research interest is fuelled by the ever-accelerating progress of technology, the growing pervasiveness of low-cost mobile devices, and their tremendous attractiveness for adults, adolescents, and children. The technological and social changes that accompany the current ubiquitous use of mobile devices are also reflected by the widely accepted notion that learning is continual and happens anywhere at any time (e.g., Gee 2003). Unfortunately, however, this stands in sharp contrast to the prevalent learning situation in schools, which is still almost exclusively focused on classroom-bound learning, mediated by a trained teacher (Sharples et al. 2002).

Traditional classroom-bound learning often forces teachers to present their material “out-of-context”, that is, in a theoretical or an abstract form. This abstraction prevents students from gaining immediate access to the inherent core of the learning material. Rather, mental effort is needed to see the relevance or practical implications of the presented material. Hence, learners in the classroom situation are often precluded from actively and dynamically constructing knowledge through interaction in the relevant learning context. Given the importance of successful learning as a constructive process (e.g., Brown et al. 1989; Lave & Wenger 1991; Papert 1980), the de-contextualized classroom-learning situation unequivocally provides sub-optimal learning conditions. To overcome the artificiality of the classroom-learning situation, didactic elements have been devised, such as providing students with examples, analogies, or exercises. For a great variety of learning goals, however, mobile learning provides a richer and more meaningful context for immediate or natural interaction with the material (Rogers et al. 2005).

Carefully designed and custom-tailored mobile classroom learning applications have been found valuable to bridge the gap between indoor and outdoor learning (Melzer et al. 2006; Moulin & Piras 2006; Rogers et al. 2005; Sharples et al. 2002). In particular, mobile learning applications serve as assistive didactic tools that contextualize learning contents previously introduced in the classroom. This is achieved by exemplifying and augmenting the students’ formal classroom learning experiences in outdoor scenarios, thus enabling the students to actively and dynamically construct an understanding of their activities (Sharples et al. 2002). In doing so, they comply with aspects that are shared in several theoretical approaches, for example, activity theory (Vygotsky 1978), constructivism (Brown et al. 1989), and situated learning (Lave & Wenger 1991).

Successfully bridging indoor and outdoor classroom learning is a complex task, which includes the use of technology in an individual, social, and organizational context. These factors comprise the heterogeneity of the people involved (i.e., teachers, students, and researchers, as well as their different motivation, knowledge, etc.), the specific learning goals or sub-goals, the methodology and devices used, economic factors, and the interrelations and dynamics between these factors (e.g., Melzer et al. 2005b). Sharples and his co-workers (Sharples et al. 2002, Taylor et. al., 2006) use the term *socio-technical system* to describe the overall complexity of the factors involved. The socio-technical system view is widely used both in software engineering and organizational psychology (e.g., Cherns 1987).

In the present paper, we report our 3-year-experience with the KiMM (Kids in Media and Motion) initiative, a research and transfer project at the University of Luebeck, Germany. KiMM promotes action-based and body-centred forms of instruction for students and teachers in the classroom (Winkler & Herczeg 2005). We will confine ourselves to one major aspect of this initiative, which is devoted to mobile and ubiquitous learning in primary and secondary schools[1].

The KiMM initiative follows an iterative design and development process within a holistic, socio-technical system view to structure the complexity of the factors involved, as well as their interrelations and interactions. Within this framework, evaluations of school projects scenarios provided an ever-increasing understanding of how to deploy, implement, and improve mobile learning systems. Iterative design and development ideally results in mobile learning resources that fit seamlessly into the complex overall situation mentioned above (Sharples et al. 2002; Taylor et al. 2006).

In the next part of this paper, we look at key concepts and criteria in mobile learning. In addition, we analyse the role of students' participation in preparing content with digital and interactive devices in the context of mobile learning. In the third section of this paper, a "hands-on" section is devoted to a description of our systematic evaluation process in respect to various practical scenarios for indoor and outdoor classroom learning. In the concluding part of this paper, we argue that the evaluation results served as an indispensable input for the iterative design and development process of digital and interactive devices to optimise the KiMM initiative's mobile learning system.

2. KEY CONCEPTS AND CRITERIA IN MOBILE LEARNING AND THE ROLE OF PARTICIPATION

Mobile technologies and devices, like handheld computers, PDAs, or mobile phones, have extended rather than replaced the existing learning tools (Trifonova 2003). This expedient coexistence benefits from the technology's advances in computing power. In addition, in most western countries, there is now a ubiquity and pervasiveness of digital and interactive devices, which are available at dramatically reduced costs compared to earlier systems just a few years ago. However, although effectiveness and availability are generally positive factors, they do not automatically implicate appropriateness or efficiency of technology.

2.1 Efficiency criteria for mobile learning

With respect to the efficiency of mobile learning, specific criteria have been identified for the selection and application of the most useful technology. We have already mentioned two of these criteria in the introduction section, namely *construction* and *contextualization*. With respect to the processes of *construction*, mobile learning applications are useful when they support students' exploration tasks in the physical environment outside their classroom. More precisely, mobile technology should encourage students to reflect, explain, and hypothesize about the physical world (Robertson & Good 2004). In doing so, new experiences relate to existing knowledge. Well-designed mobile learning systems thus entail cognitive

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[1]Other KiMM research activities focus on interactive mixed-reality performances and installations, and web cooperation and pervasive gaming, respectively (see also http://www.kimm.uni-luebeck.de).

processes known to be essential for human memory, namely verifying, elaborating, and deeply processing study material. This provides a superior basis for later successfully retrieving the learned material (e.g., Craik & Lockhart 1972).

With respect to *contextualization*, adequate mobile learning systems provide the means for interaction in the relevant learning context — a notorious problem of de-contextualized classroom-bound learning. Yet, the term learning context is not restricted to the situation of merely being in a different environment or location outside the classroom. Rather, context is constructed through the students' interactions with the mobile learning systems. This form of context includes the technological aspect of using mobile systems (e.g., the system functions and the supported I/O channels). Lastly, the context of using mobile systems also has a significant social or even community aspect, which involves the learner, other co-learners, the teachers and their parents (Barnard et al. 2007; Taylor et al. 2006).

The social aspect points to a third efficiency criterion of mobile learning systems, namely supporting learning as a continual *communicational process*. A shared understanding of the world evolves through mutual communication. With respect to designing mobile learning resources, systems are superior that provide students with a heightened sense of awareness to the activities of other members of the community context, and/or support multiple conversations between the members (Kraut 2003). This may be achieved, for example, with networked computers that allow for mutual discussions, respectively (Sharples et al. 2002).

2.2 Participation in preparing mobile learning

Since contextualization, construction, and communication, have only been described from a theoretical view so far in this paper, this section is devoted to transference of efficiency in designing and implementing practical mobile learning scenarios. The mobile learning approach introduced in schools projects should be designed to maximize the above-mentioned criterion in every stage of the project. This includes indoor or classroom preparation, the actual outdoor experiences, and the concluding presentation and discussion phase, which typically occurs back in the classroom. To this end, Figure 1 shows a simplified representation of the "current or commonly used" approach to designing and deploying mobile learning projects in schools (upper half), and the approach of the KiMM initiative at the University of Luebeck (lower half).

Both approaches place heavy emphasis on active contextualization, communication and construction throughout the outdoor mobile learning experience and the concluding reflective phase. The students use mobile devices (e.g., PDAs, external sensors) for retrieving information and recording their findings, and they make use of the system's connectivity to other media to present and discuss their experiences and findings with other members of the learning community (i.e., students and teachers, locally and globally). Putting students, or learners, in active control of learning so that they select, use, and modify the technology and devices, denotes another important efficiency criterion in mobile learning, namely *control* (e.g., Taylor et al. 2006).

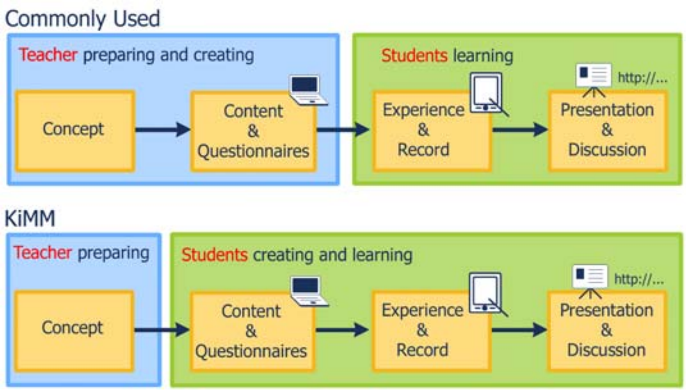

Figure 1. Two approaches that differ in students' active participation in creating outdoor learning material. Students are either involved in the construction process that occurs in the classroom (*"KiMM"*), or not (*"Commonly Used"*)

The KiMM approach, however, significantly differs from the commonly used approach with respect to the students' role in mobile learning. In the commonly used model, the students' experience two separate constructional processes; one that takes place inside the classroom with the teacher introducing a certain topic (e.g., the biology of flowers), and a second constructional process that occurs in the outdoor situation supported by mobile technology (e.g., a field trip to a botanical garden using PDAs). The meshing of construction, however, does not occur seamlessly. Although students are integral participators in the classroom communication, they are excluded from the authoring, or *construction*, process during the technological preparation phase for outdoor leaning. Hence, the students are likely to experience a gap between formal classroom learning and outdoor learning situations. Thus, the contextualisation (or transfer) of classroom learning content is disjointed for the students. This apparent gap between indoor and outdoor learning is by no means a novel finding. Rogers and colleagues (Rogers et al. 2005) have already concluded that "this separation of interlinked activities can make it difficult for children to see and understand the connections between what are essentially the same representations and processes being studied, albeit in different contexts" (p. 56).

The ultimate of the KiMM approach is to fully involve the students from the preparation phase onwards. Thus, they actively construct and control the authoring process of creating the content. This encourages students to reflect and hypothesize about what they have learned (i.e., constructed) so far, and how this may relate to the physical world they are about to experience. Technically, they create questionnaires and testing kits using KiMM's Moles software system (see next section), which are then transferred to the Mini Moles software that runs on PDAs (Melzer et al. 2006, 2005a, 2005b). The benefits and advantages of students' early involvement in technologically oriented design processes based on participatory design have already been demonstrated (Guha et al. 2005). Moreover, when the students are controlling the preparation phase under the teacher's supervision, they gain another valuable source of validation for their own hypothesis, or constructs, acquired during the initial classroom learning situation.

In the next section we present various practical examples for KiMM approach. In addition, the description of five mobile learning scenarios reveals the beneficial influence of systematic evaluations in iterative design and development of the KiMM initiative's mobile learning system.

3. "HANDS-ON": USING EVALUATION METHODS FOR ITERATIVE MOBILE LEARNING SOFTWARE DEVELOPMENT

The socio-technical system view predicts that different media technologies and applications will yield positive learning effects. This is due to the specific mix ratio of the technology and its social and organizational context. Therefore, we designed a flexible evaluation framework (i.e., questionnaires, final project reports, and interviews; Melzer et al. 2005a). The evaluation method was adjusted according to the scope of the learning material, the specific age-group of the class, different target groups (i.e., teachers and students), and range of hardware and software used in the project. The evaluation process comprised fixed core elements for the detection of general changes from one measurement point to another, as well as adaptable parameters (i.e., items).

3.1 General evaluation method

In all of our projects, the students were required to record, in project logs, their observations and reflections throughout the project duration. These protocols listed what tasks they were to do when, their general observations about group dynamics, communication difficulties, technical glitches, end results, and their own feelings about working in a media-supported collaborative work project. The teachers submitted final project reports, which were a résumé of the projects, as well as their own experiences and suggestions on how to improve the learning experiences and technology. At the end of the project, the students, teachers, and researchers participated in either a classroom discussion round or a feedback session.

In five KiMM mobile learning projects, a total of 347 students, 26 teachers completed approx. 17,000 questions (either pre- and post-project questionnaires, or only post-project questionnaires). The following parameters were included in the questionnaires. Each parameter used a scale-like measure, contained a varying number of items, and differed in scope according to the specifics of the project in consideration:

- Previous exposure to/experiences with media (e.g., *"rate your own computer expertise"*)
- Students' cognition, problem solving (e.g., creativity: *"did the device support/trigger new ideas?"*)

- Students' emotion (e.g., motivation, emotion, satisfaction: *"satisfied with personal outcome?"*)
- Students' behaviour (e.g., teamwork: *"fair distribution of devices among group members?*)
- Media (e.g., handling, applicability: *"device/application well-suited for the task at hand?"*)
- Expectation and apprehension (e.g., concerning the curriculum: *"learning goals fully met?"*)
- Judgment of KiMM support (e.g., *"sufficient training before using the devices?"*)

We have presented detailed analyses of the pedagogical success of various KiMM initiative's mobile learning projects elsewhere (Melzer et al. 2006, 2005a, 2005b). Hence, in the next section we will briefly describe five consecutive project scenarios, the quintessential information derived from the evaluation process, and the resulting software application.

3.2 Selected projects and iterative design of mobile learning systems

The subject material of each KiMM mobile learning project was derived and then contextualized from the class curriculum and elaborated in close cooperation with the teacher. This contextualization approach bears close resemblance to the concept of *contextual design* in software engineering, which has become a well-established approach for consumer-centred systems. Contextual design combines field analyses within the users' natural environments, requirements analyses, systems conceptualization, and testing (Holtzblatt 2005). In the KiMM initiative, testing refers to the evaluation results that substantially influence the choice of content material and introduced changes in project planning of future projects. With respect to the process of iterative mobile learning software design and development, each project yielded valuable information that pointed the KiMM team in a further direction for optimizing or adapting the mobile learning system.

3.2.1 Early attempt at mobile learning

In an early practical application, a prototype scenario titled White Spot History Hunt (WSHH), a member of the KiMM initiative and 8th grade high school students designed an interactive history scavenger hunt (Melzer et al. 2005a). WSHH was a pervasive game, which was settled in the time of the Industrial Revolution. The WSHH teams used smart phones to discover a series of white spots on a virtual map of 19th century Luebeck. Navigators and history hunters were located in school classrooms and used an Internet chat program to communicate with the runners in the city.

The evaluation of the prototype showed that, though students and the teacher enjoyed the project, they were overwhelmed with the high level of technological complexity. More importantly, we were not satisfied with the level of control and contextualization (e.g., students not being able to edit content). Thus, we designed the Moles and Mini Moles software system to reduce complexity and increase the students' involvement in the preparation phase. This system combines mobile and classroom learning to further the process of construction (Melzer et al. 2006, 2005a, 2005b).

3.2.2 Mobile Weather Project

A 7th grade class created a Mobile Weather Project to determine, analyze, and record, the variation of weather elements in their inner city environment. The students researched and used material acquired from three class subjects (geography, mathematics, and physics) to create interactive multimedia questionnaires using the JAVA based and XML structured Moles software on laptops (Figure 2). Then, the students participated in a field project day. They measured and recorded weather information at five different locations distributed throughout the city using the Mini Moles software on PDAs. In this project the students used a variety of hardware (laptops, handheld GPS, various external sensors to record air pressure, temperature, and wind velocity, PDAs, and digital cameras), as well as software (Moles, Mini Moles, GIMP graphic software, Open Office text program) (Melzer et al. 2005a, 2005b).

In the evaluation of the Mobile Weather Project, both students and teacher stated that the otherwise successful experience suffered from insufficient communication and a lack of awareness of the actual status of other group members. Since awareness is a key issue in computer-supported collaborative work (Kraut 2003), it is necessary for the software to allow for communication between the geographically separated groups. This was also true for the communication between the teacher and the KiMM team in the school. The resulting software advancement, Mini Moles NET, is currently under development.

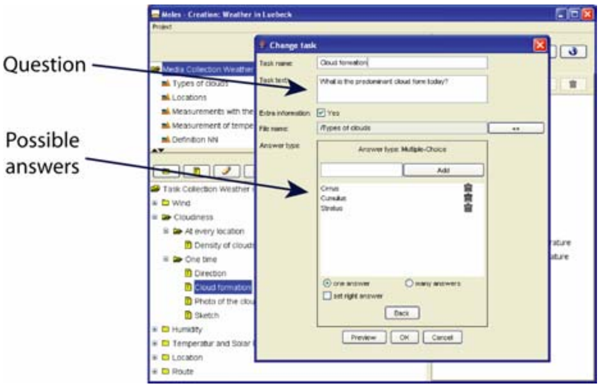

Figure 2. The Moles software GUI with text field for formulating questions (*upper arrow*), and field for preparing multiple-choice alternatives (*lower arrow*)

3.2.3 Mobile Advent Calendar

In this project, 10th grade students created a Mobile Advent Calendar for the first year high school students (5th grade). The 5th graders, new to the school and unfamiliar with the surrounding neighbourhood, went on a digital treasure hunt inside and outside the school to discover the "doors" of their mobile Advent calendar. They were equipped with PDAs (Mini Moles), GPS, and digital cameras. Each "door" bore a surprise for the 5th graders (e.g., Christmas carols sung in Latin, Spanish, French and English, recited poems by fellow students and teachers of the school).

The 5th grade students (10-11 years old) indicated that the GUI might be sub-optimal for young students in terms of control (Melzer et al. 2006). Hence, we developed the Moles-for-Kids software (Figure 3). Its intuitive GUI (icon-based programming) can be used in mobile learning projects from primary schools grades upwards.

Figure 3. GUI for Moles-for-Kids software. Rather than using the standard folder-and-text-button interface, editing and programming, Moles-for-Kids is supported by coloured icons and an assistant helper

3.2.4 Children, Children!

In this museum/school project, a 5th grade class studied the lives of children at the turn of the 18th century (German, history, and music classes). They created aesthetic biographies of five fictitious children (e.g., orphan, pastor's son, aristocrat's daughter) in blogs. The students used this material to create a pervasive game (history hunt) with Moles on PCs and then transferred the interactive multimedia questionnaire to Mini Moles on PDAs. The gamers used PDAs in a local castle, now museum, exploring the role of art, education, fashion, hygiene, music, and nature, in the lives of children in the 18th century.

Post-project discussions introduced the necessity of developing an automatic or manual localization modus that renders information (i.e., clues and tasks) available to students only if they were physically present. This option would create a greater game feeling to scenario-based mobile learning games. The teachers also said they needed assurance (i.e., control) about whether the unsupervised groups actually physically visited the various locations during the outing. In addition, preparing the routing material in the classroom for the users to navigate from one location to another was time consuming (Melzer et al. 2006). Thus, a route-guiding system was thought to meet the requirements of control and construction. The resulting software advancement was named Mini Moles Loc.

3.2.5 The Fate of Dr. X

In this prototype project, 6th grade students learned that the university hospital is not only as a place sick people go to, but also a place where thousands of people work and study. The students played a pervasive detective game using the Mini Moles Loc system (Figure 4), which required navigating their way around the large hospital and university campus with PDAs and GPS device. The students went from one hospital location to another, trying to figure out the fate of Dr. X (a fictitious character), who was reported to lie in a coma in the inner medicine ward.

Figure 4. Students playing "The Fate of Dr. X" (photo middle). Screenshots from the Mini Moles Loc GUI (on a PDA) are displayed on the far left (*map navigation*), and on the far right (*multiple choice questions*), respectively

In the pervasive game, automatic GPS localization or manually entered code words (derived from physical indicators (e.g., building addresses or exhibit numbers), turned the whole project into a Geogame format (Kiefer et al. 2006). This enhanced the students' motivation and learning experiences by combining educational content with location-based information systems and the physicality of their environment. The next version of Mini Moles Loc will extend the current limitation for students to edit the map navigation.

4. CONCLUSION

Educational research has to acknowledge the challenges of advancing technological progress and increasing availability of mobile systems and devices. An expedient response to this challenge ties together technological progress and its growing availability, the conviction that learning is no longer bound to the classroom but takes places anywhere and at any time, and encouraging learning experiences through various mobile learning approaches.

In the present paper, an approach was described that addressed the complex situation of mobile learning systems in the context of classroom-oriented curricula. We presented a summary of the 3-year-experience with the optimization process from the KiMM initiative at the University of Luebeck, Germany. This optimization rested on an iterative design and development process; a well-established approach in software engineering. The iterative process included thorough analyses of the requirements (e.g., curricula, goals, and economic factors), participatory design and contextual design, carrying out school projects in which students use systems and devices; always focusing on the efficiency criteria for mobile learning.

Five consecutive mobile learning projects were described that used and evaluated different versions of the Moles and Mini Moles software system. With each project and evaluation in the KiMM initiative, a step further was made in the system's evolution: its functionality advanced in terms of control (i.e., age-appropriateness in handling), communication (i.e., social awareness), and contextualization (e.g., displaying geographical information). The next step, for example, is to develop a web-based globally accessible version of Moles, and a Mini Moles version for mobile phones, which are now commonly used amongst students. The Moles and Mini Moles system will never be completed, thus acknowledging the complex and idiosyncratic responsibility for creating mobile learning systems for schools.

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