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PHYSICAL ACTIVITIES AND PLAYFUL LEARNING USING MOBILE GAMES

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The combination of informal learning and mobile outdoor games can be seen as a relevant arena for conducting novel learning activities that involve children in different tasks including physical motion, problem solving, inquiry and collaboration. These are activities that support different cognitive and social aspects of learning. Co-design and human centric design practices have been the focus of current research efforts in the field of educational technologies but not as prevalent in mobile games to support learning. In our current research we are exploring which design methods are appropriate for developing innovative ways of learning supported by mobile games. This paper presents all those aspects related to the design and implementation of a mobile game called Skattjakt (Treasure Hunt in Swedish). The outcome of our activities has provided us with valuable results that can help additionally to integrate outside informal learning with more formal classroom activities. Moreover, we believe that involving children in the design process of mobile games may give us new insights regarding the nature of their learning practices while learning with games.

Keywords: Ubiquitous computing; mobile games; informal learning; co-design; digital maps.

1. Introduction

Current developments in mobile, wireless and positioning technologies combined with contextual computing are contributing to the advance of new mobile applications and services. The rapid adoption of sophisticated mobile devices and applications has created new social tools for people to connect and interact, therefore changing the ways we communicate and collaborate. These new forms of mobile communication and collaboration are rapidly being adopted and integrated into young people's everyday lives. Multimedia capable mobile phones, MP3 music players, digital cameras, and GPS devices are merging into single powerful units that rival the computational power of laptops at a fraction of the cost. One of the main assumptions we consider as a point of departure for the ideas that guide our work is

the fact that in the coming 5 years, whether educators would like it or not, more and more students will bring these kind of devices into the classroom. Mobile technologies could be then used to enrich and support innovative ways of learning, shifting the focus away from the computer screen to other places of interest. Rogers and Price (2006) argue that students could use mobile and ubiquitous technologies to interact with new media in the physical world in totaly different ways compared to the traditional modes of interacting with digital information at a computer or exclusively with the physical world. Lankshear and Knoble (2006) claim that many schools ignore some of these developments and argue that mobile and ubiquitous technologies and new media might be 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 the use of digital games. Until recently, the use of computer-based games has struggled to be taken seriously within the formal educational community. The recent proliferation of mobile games makes them a fertile ground for the development of new resources to support learning (Facer *et al.*, 2004). Mobile games can promote children getting involved in different tasks such as exploration, content generation, collaboration, problem solving and navigation in space; all these activities can be seen as important components that support a wide variety of cognitive and social skills.

It is our belief that the active involvement of young people in co-design and human centric design practices regarding the development of mobile learning offers new dimensions and opportunities to explore and promote novel ways of learning. User and learner centered design practices have been the focus of much research in educational technologies in recent years. However, far less discussion and effort has focused on the process of designing innovative educational activities using mobile games. As mobile technologies are already an integral part of young people's homes and social places, we face new problems and issues that pertain to the optimal use of these technologies to support learning. Therefore, the focus of our current research can be formulated as follows:

Which design methods are appropriate for developing novel learning activities using mobile games?

This article presents those aspects related to the design and implementation of a mobile game called Skattjakt (Treasure Hunt in Swedish). We discuss the results of the activities we have conducted with 38 young people that played this game in informal learning settings during 2007. Skattjakt has been conceived and developed to encourage young people to get physically active by solving a mystery surrounding a castle located on the university's campus. The game is inspired by the ideas behind treasure hunt activities and the sport of orienteering, a traditional Scandinavian running sport involving navigation with a map and a compass. Initially, Skattjakt started off when members of the CeLeKT research group had a meeting

with Mapping Växjö, a community initiative to promote the sport of orienteering and Natverketsip, a local NGO. During this meeting all partners discussed how to get more young people interested in physical motion and sports, by participating in challenging activities supported by new technologies. After this initial meeting, we decided to approach the project from the needs of designing a game that could be played outdoors during the winter at night using mobile phones. One of the first ideas was to provide some type of interactive map to be displayed on the phone, so that the players could use it for navigation. Working together with stakeholders and with students from a mobile game course at our university, the game concept was developed and then play-tested iteratively with the students. After the success of the initial game during the winter 2007, we were able to expand and integrate the game into a summer program for girls aged 13–15 that was coordinated by the local municipality.

The paper is organized as follows. In the next section, we present the theoretical ideas that guide our design, while Section 3 gives an overview of the recent efforts in the field of mobile learning games. Section 4 illustrates the details of the game, including a brief description of the differences between Skattjakt and similar mobile games. In Section 5 we describe the technology behind Skattjakt. Section 6 describes the results of our two trials based on the analysis of data we gathered from surveys, interviews, observations, and post game workshops with the players. Sections 7 and 8 conclude this article by providing some conclusions and a description of current and future directions of our work.

2. Theoretical Perspectives

Social constructivism, an extension of the constructivist approach, argues that in addition to most knowledge being an interpretation of personal experience, knowledge is also social in nature and is jointly constructed in interaction with others. Recent social constructivist perspectives (Jonassen & Land, 2000) regard learning as enculturation, the process by which learners become collaborative meaning-makers among a group defined by common practices, language, use of tools, values, beliefs, and so on. Social constructivism asserts that a particularly effective way for knowledge-building communities to form and grow is through collaborative activities that involve the design and construction of meaningful artifacts as well as the exchange of information. An implication of this view on learning with regard to the design of novel educational activities supported by mobile technologies is that effective and meaningful learning may not take place if these technologies are only used in traditional ways. Thus, a challenge is designing and implementing learning activities that support innovative educational practices.

Co-design can be defined as a highly facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes and evaluate each prototype's significance for addressing an educational need (Penuel *et al.*, 2007).

The co-design process relies on teachers' ongoing involvement with the design of educational innovations, which typically employ technology as a critical support for practice. What can be lacking form this approach is the absence of the actual learners/students in the design process. This is where approaches such as Cooperative Inquiry and Learning by Design can be used to explore how iterative cycles work with adults and kids to create innovative technology for children (Guha *et al.*, 2004; Kolodner *et al.*, 2003).

Based on approaches such as co-design and learner centred design, it can be observed that design is central in efforts to foster learning, create relevant knowledge, and advance theories of learning and teaching in complex settings. These concepts are also consistent with the ideas behind design-based research, an approach that combines the intentional design of interactive learning environments with the empirical exploration of our understanding of how these environments and how they interact with individuals while keeping innovation in focus (Hoadley, 2004). By taking this explorative approach as a point of departure, we can investigate through design how to develop different learning opportunities for children not only to learn through experiences, but also to learn by becoming game designers. This myriad approach can provide us with ways to gather insight on the design requirements of challenging and novel activities. One of our aims is to explore how learning innovations that take place outside the formal educational system can be brought into schools and how children can gain new and different insights on the nature of their learning practices when they become designers of new materials.

3. Mobile Games and Learning

An increasing amount of scientific publications indicates a wide research interest in exploring how mobile games can be designed and used to support a wide range of intellectual activities. Researchers and educators are looking at how to incorporate some of these new literacies into education (Rogers & Price, 2006). Promising results have been reported, although the majority of them are more driven by technology and have not always incorporated the actual learners or teachers into the design process. There are some exceptions, and in this section we will present a brief overview of some of these games.

Environmental Detectives is an early mobile game that used personal digital assistants (PDAs). The game has engaged high-school and university students in a real-world environmental consulting scenario constructed to immerse players in the practices of environmental engineers, giving them a "virtual practicum" experience, similar to working on an environmental research team. Students played environmental scientists investigating a rash of health concerns on site linked to the release of toxins in the water supply, a scenario loosely based on actual historic situations. The main focus of the game was on planning an effective investigation that balanced quantitative and qualitative data (Klopfer *et al.*, 2002). Another example is the Savannah project, a mobile game that re-creates the African savannah outside

on local school grounds. The game consists of two related areas of activity. In the first, children are able to play at "being a pride of lions" outside in a playing field (100 m × 50 m), interacting with a virtual savannah and exploring the opportunities and risks to lions in that space. Children are given global positioning systems (GPSs) devices linked to PDAs through which they "see", "hear" and "smell" the world of the savannah as they navigate the real space outdoors. The second playing field, the "Den", is an indoors space where children can reflect on how well they have succeeded in the game, access other resources to support their understanding and develop strategies for surviving as lions in the virtual savannah (Facer *et al.*, 2004).

In Capture the Flag (CTF), robust standard mobile technology and traditional game play are used to provide a physical experience outdoors. The game provides collaboration between field and stationary players in mixed reality environment by combing mobile game play with PC based visualizations and mobile electronic flags that are displayed and tracked with the players enhancing game play. Although CTF has not been designed to be used for pure educational purposes, it raises interesting questions about the possibilities of mixing the virtual and physical worlds for active game play (Cheok *et al.*, 2006). In SupraFly, a community-based soap opera, players create characters and interact through them. Players score points by making and maintaining relationships. Interaction occurs via the mobile phones using SMS and through a companion website where the players can track and further develop their characters. Using SMS and the users's own phones, SupraFly explored social aspects of mobile game play but lacked a connection to relate the game to physical activities and different type of tasks that could trigger new game interactions (Jegers & Wiberg, 2006).

Frequency 1550 is a historical based game in which groups of students are competing acting as pilgrims in old Amsterdam while trying to find a holy relic. Each team has members located at headquarters and exploring the present day streets of the city. The outdoor players communicate via videophones and use a GPS equipped mobile phone for the game and position tracking, while indoor team at headquarters had a laptop connected to the internet. The teams at headquarters track all the teams and can direct their own team in the street. Frequency 1550 is a serious mobile game effort that follows a standard design approach for development where the educational and technology was developed and then tested with a local school. Part of the initial pilot was an all day debriefing with the students, teachers, and researchers. Recently, Frequency 1550 has been tested with 250 students in a more controlled experiment where the students were divided into groups to explore how collaboration and narrative influenced learning in this mobile game (Raessens, 2007).

The COLLAGE (Collaborative Learning Platform Using Game-like Enhancements) project brings to secondary school students and their teachers a mobile learning platform for context-dependent and location based games. Fun, interdisciplinary collaboration, and challenges are combined to create new learning opportunities beyond the four walls of the classroom. The COLLAGE platform supports

the authoring and playing of a board-like game on a site of educational interest. The game is played with the aid of mobile learning technology (mainly mobile phones, PDA's, and GPS technology) that relies on direct communication with the players situated on site or in the classroom. The project group in COLLAGE consisted of researchers, teachers, and software developers. COLLAGE utilizes a game-like learning approach that helps teachers to create mobile learning experiences to support curriculum together with an implementation guide and web-based interface for creating and designing the game (Sotiriou *et al.*, 2008).

4. Skattjakt: Game Description and Design

Skattjakt is a game that has been conceived and implemented to promote physical activity and collaborative problem solving by the unique combination of practicing orienteering using mobile technologies. The game explores informal skills in map reading and learning about local history, and requires different degrees of collaboration between team members to solve the mystery. Up to six teams can compete simultaneously using mobile phones, as they progress through the playing field with detours for wrong answers. A strong narrative drives the players to help a ghost solve a mystery about her lost husband who built the castle on campus. The playing field is spread out over the university campus with six locations and a final goal at the original farmstead. The mobile game application we have developed provides an interactive map with the different locations marked in a way that the players can zoom and pan to see the entire playing area. Figure 1 illustrates the full map of the playing field with the detours. Children playing the game can, via a mobile phone, communicate with the game server that provides the logic for the game.

The players need to find the markers and receive text and audio based clues via the game phone by navigating with the mobile-based map. Figure 2 illustrates the different game modes on the mobile phone, with (a) in map mode, (b) audio clue from the ghost, and (c) a question screen. Once they find the location they need to collaboratively solve puzzles, decode numbers, and find orienteering flags and other landmarks. The game starts with a video introduction describing a particular mystery surrounding the castle. The ghost of Anna Koskull, former lady of the manor, has contacted the *Center for Electronic Voice Phenomena* (fictional research group at our university) with a series of videos asking for help to solve the mystery surrounding her husband's obsession with numbers and untimely death. She has only one day every century to find the answers to escape limbo. The day of the game is that day. From an educational game point of view, the design ideas that guide our work are inspired by "epistemic games" (Collins & Ferguson, 1993) and expanded by recent efforts explored by Shaffer (Shaffer, 2007). For our particular case, we want to encourage children to think like historians and investigators of the paranormal when it comes to know about the history of the castle on campus and the geography surround it.

Figure 1. The game map with markers and detours.

(a) (b) (c)

Figure 2. Illustrates the game screens, map mode, ghost mode, and question mode.

(a) (b) (c)

Figure 3. Game play, team collaboration, physical activity, and mobile interaction.

Figure 3 illustrates different stages of the game play process, as following: (a) collaboration between team members, (b) physical activity, and (c) interaction with the mobile handset. In the second trial we conducted during the summer 2007, each group had an additional mobile phone with a camera for self-documentation of what happened in the different positions of the game.

4.1. *Design practices*

The first trial was conducted during the winter 2007. It took its starting point from co-design, where researchers, developers, stakeholders, and university students from a mobile games course worked together in a series of workshops defining and refining the game concept. The technical platform for the implementation of the game was kept to a minimum, as the developing team decided against the use of GPS devices due to the time limit of developing a custom solution for integration with our software application. Semacode and other 2D visual bar code systems were also ruled out due to nighttime light conditions (Semacodes and other visual barcodes can be used by camera phones to trigger events when the image is decoded by software in the phone under good light conditions: for more info see, www.semacode.org). The design challenge was to create a concept that did not require a score collection mechanism, but instead had penalties for wrong answers that involved the campus as the playing field. Working as a team we refined the story using historical figures that lived on the campus. We physically play tested different schemes for penalties before arriving at the current scheme, as described in Figure 1 for the map and detours. The playing field also provided different starting points for the six teams. The pilot game was tested with 12 after school children age 12–15 on February 23, 2007. The main objective for this pilot was to try our *proof concept* regarding both the activity and the technology. Moreover, we wanted to explore how we could combine an informal learning activity together with physical actions and history subject matter.

From the success of the pilot game, the project progressed to be part of a weeklong summer school program for technology and design offered for girls age

12–15 in the municipality of Växjö (June 2007). Our intention for this trial was to expand the research approach by using design strategies to explore how to shift the informal learning goals to more of a formal approach. Additionally, we wanted to look at different ways to evaluate results from the game and workshops. Twenty-six of the summer students played the game. For the second day workshop we recruited ten of the older students ranging from 13 to 15 years of age. In addition to the usability survey from the pilot, we provided an extra camera phone for each time to self-document, used observation forms, and conducted some sample interviews with students. Since the game was part of the summer school program it offered the opportunity to for us to see how co-design and human centric design could be applied when directly involving the students.

For the workshop, we divided the students into four parts. The first part of the process began with an introduction to game design where we dissected Skattjakt. In the second part we detailed the game components and rules, and the students were broken into two groups. Each group brainstormed different game concepts and then presented to each other to get feedback and to refine the concepts. After lunch the girls recruited some of the other students for a small play test for each of game ideas. Figure 4 documents some of the outcomes of the workshops during the presentation of the game concepts before play testing. Image (a) is one of the groups presenting and image (b) is a close up of the game flow concept created by the students.

4.2. *Differences between Skattjakt and other similar games*

The examples of similar games described in Section 3 show promising results regarding the use of mobile games in informal educational settings. From a design point of view, some of these efforts have used design practices that have brought the players into design process. In particular, the COLLAGE project (Sotiriou *et al.*, 2008)

(a) (b)

Figure 4. The workshop presentation and results.

allows both teachers and students to create games by using a specific web based authoring toolkit developed for this purpose. The rapid prototyping approach we used for Skattjakt combined with an active participation of the children in the different phases of design process offered us some advantages over these games by providing us insight on design and evaluation of future mobile learning games. The combination of the learning activity together with the creation of new mobile games provides new possibilities for exploring the potential impact of mobile games in education. Additionally the Skattjakt design process has aimed for the direct involvement of not only teachers but also players/learners from the start, providing easier ways to promote innovative educational practices. By working with the players and involving them in the creation of new game concepts based on Skattjakt, our aim is to gather new knowledge related to the requirements and design of new mobile learning tools that can engage students while providing insights to the design challenges for mobile game based learning.

5. Technical Aspects of the Game

Unlike our previous work regarding the design and implementation of mobile and ubiquitous learning (Kurti *et al.*, 2008), we opted this time to keep the technology in low fidelity mode, giving us a rapid prototype approach that allowed a more thorough exploration of the design process. For Skattjakt, we developed an Adobe Flash Lite application running on each phone that communicates with the Activity Control System (ACS) (See Figure 5 below). The ACS is a software application we have implemented that controls the flow of the different activities based on a predefined logic and user input. The ACS is part of larger system the Learning Activity System (LAS) that we have developed that also includes the Collect, Convert and Send (CCS) repository for the data handling. The communication between the Flash Lite application and the ACS was implemented by using the Post Variables programming features of the Adobe Flash Action Script language.

When the phone sends a request to the ACS, the returned value is a XML string that is parsed in the Flash application running in the phone. The Flash application was designed in a way that the International Mobile Equipment Identity or IMEI number for each phone is included in the ASCII string sent to the ACS server, as well as the unique ID activity number that can be identified by the ACS that will generate a new activity according to the value of these variables.

6. Elaboration of Results

We have used an ethnographic approach that combined playing the mobile game with more formal experiences of the co-creation of new games in workshop settings. We have written field notes, made interviews, have been "hanging around," collected documents used in the different learning situations, and in addition have had deep interviews with teachers and learners. The aim of using ethnographical methods has been to "come closer" to learning in real settings, find out "how learning is

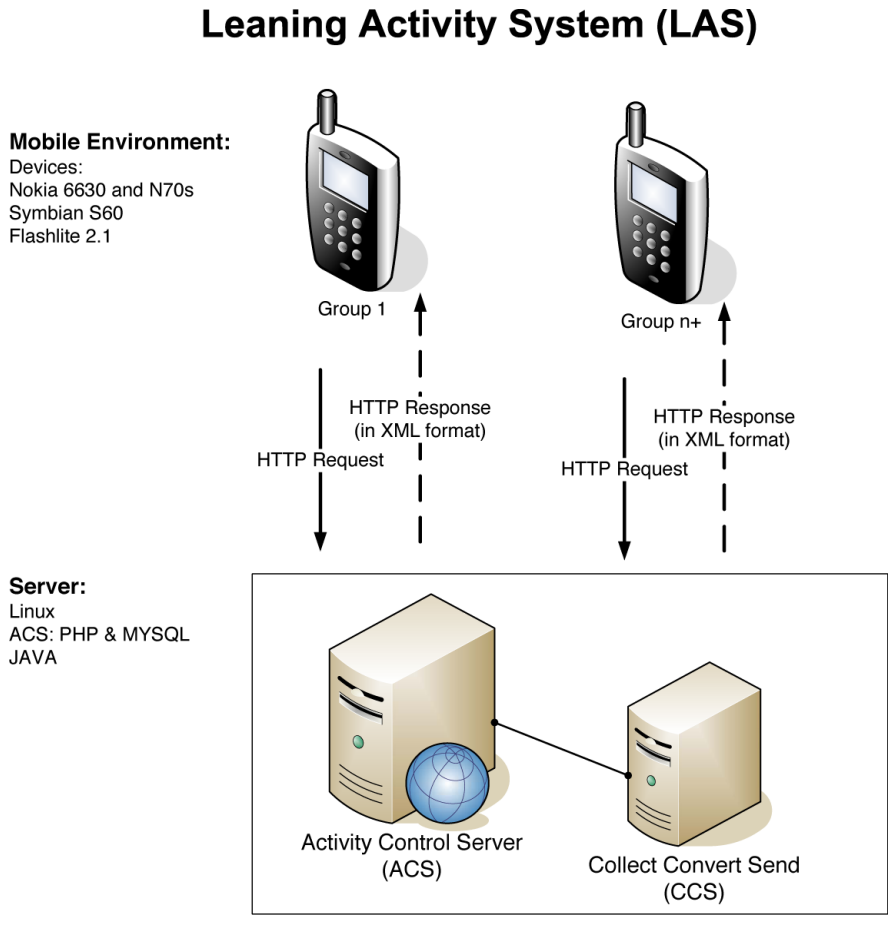

Figure 5. The mobile and server communications of the LAS.

taking place" — how artifacts are used, how the content of learning is established, what the interaction between the participants looks like, and so on. According to Vavoula & Sharples (2008), mobile learning should be evaluated according to the following 3 levels namely: a *Micro level*: assessing user's experience of the technology including usability aspects and utility of functions, a *Meso level:* looking at the user's learning/educational experience and a *Macro level:* in which the evaluator tries to understand the impact on learning/teaching practice as well as the appropriation of the new technology and new practices. All these different levels can help understand some of the on-going learning processes as well as assist us to identify problems and further requirements. The results presented in this section look at the experience of the game and workshop, and the knowledge motivation and domains. Using this approach enabled us to use various methods for data collection about the different activities with a loose framework for evaluation. In the first pilot trial we used

only surveys. In the second trial, along with surveys, we used photographic self-documentation with additional mobile phones, simple observation conducted by researchers, and a daylong workshop for the some of the players, which resulted in new game concepts. By looking at the results, we begin to see some patterns across the surveys, interviews, and the photographs the students made during the experiment.

The data from the interviews came from a selection of six girls from the second trial where four of them also participated in the workshop activity. The interviews were conducted during the workshop the day after the game. We also used observation and procedures sheets developed in one of our other projects that help observers to look at aspects such as attitudes, engagement, collaboration, understanding of the task, the game experience, roles of players, and cultural issues. The six observers were a mixed group of researchers, university students, and members of the local orienteering club.

6.1. *The game experience*

In order to evaluate the game experience we coupled together data collected from the interviews, observers, and the surveys. Based on the observations from the researchers the game was a viewed as a good and fun experience by the players. The girls responded in the interviews that the activity was fun and all of them would like to try the game again in different subject matters in addition to history. They felt that the questions were challenging and this created curiosity and suspense as they worked their way towards the final goal. As described by one the players below:

‘‘You didn’t get bored, would love to do something again’’

We used observation sheets to examine attitudes towards mobile technologies and usability. Little problems were encountered during the activities regarding technological aspects. Some reported problems were related to using the game interface and two instances of shutting off the phone by accident. In both trials the surveys showed that the response was very positive regarding the game experiences and for ease of use of the mobile application. In the first trial conducted on an early evening of a cold winter night 58% responded that the game was very exciting and 42% only exciting from a total of 12 students that played the game.

The second trial conducted during daytime in the early summer showed 73% of the players finding the game very exciting while the remaining 27% as exciting from a total of 26 students. See Figure 7, graph (a) for a visual comparison. Ease of use for the technology breakdown is as follows; for the first trial 50% expressed that the technology was very ease to use, 42% easy, and 8% not so easy from a total of 12 players. For the second trial 23% reported the game was very easy, while 73% easy, and 4% not so easy reported from a total of 26 players. Figure 6(b) illustrates these results.

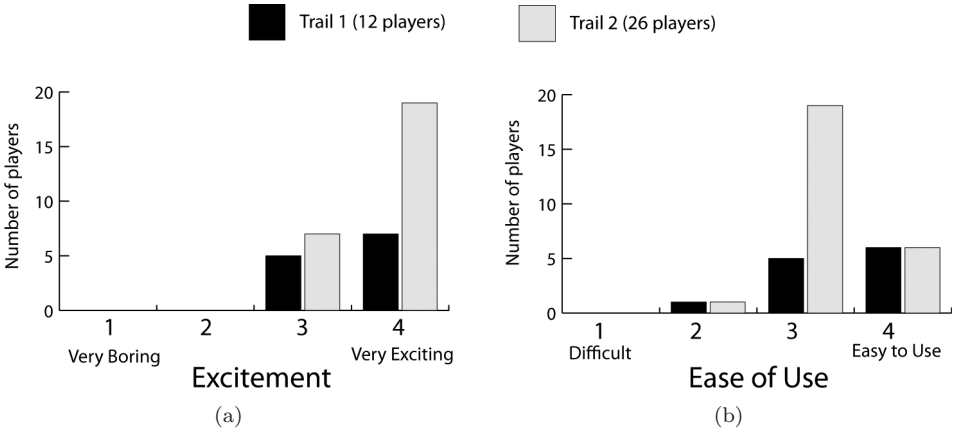

Figure 6. Diagrams of the two trials in terms of excitement and ease of use.

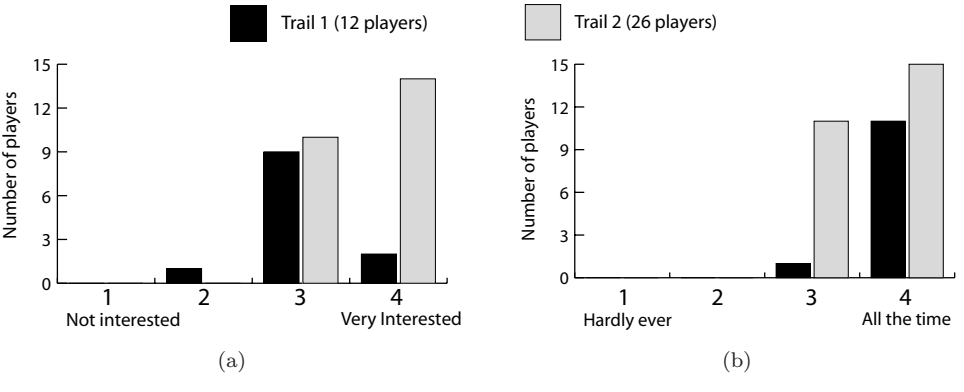

Figure 7. Diagrams of the two trials for motivation an collaboration. (a) Motivation via technology. (b) Collaboration during game.

6.2. *Motivation and collaboration issues*

The elaboration of the motivation issues and the domain of the game presented some interesting results. The players felt very engaged to learn by playing the game with the phones. But when asked about what they learnt they felt they learnt only a moderate amount about local history. During the interviews the girls reported that when they got engaged in the game, they wanted to know more about the history subject inherent in the game as they went along. As one of the students described:

‘‘There is a different feeling running when you have an added reason to do it’’

From the analysis of the observations collected by the team, the actual fact of playing the game rather than the narrative motivated the players. The story had

little relevance for them, although the observers reported that the players responded to the main character, the ghost of Anna Koskull. The data from the surveys illustrate that the excitement of using the mobile devices was rated high along with collaboration between team members. For the first trial, 75% felt motivated to know more about local history by playing the game, while 17% thought it was a very good way, and 8% felt neutral about using mobile devices in this context. At the second trial, 58% responded it was a very good way and 42% felt it was good. Figure 7(a) presents the motivation to learn more about history by playing the game. The players in both trials reported that they worked together almost all the time when playing the game. In the second trial the groups consisted only of girls and they collaborated all the time at 92% of the cases, while in first trial of mixed groups all the time was 58% and most of the time 42%. Figure 7(b) shows how the players perceived their collaboration during the game.

Collaboration between the players in both trials was highly rated by the players and the workshop attendees based on data we collected from the surveys. Based on the outcomes from the interviews, collaborating with other girls made them get to know each other better and created a team spirit. It was more fun to run and solve the problems together than alone:

‘‘It was much more fun than just running; we helped each other. Usually when you run, you do it alone.’’

The observers reported that the features of the game were driving factors for motivation and collaboration since the competition forced them to work together. The different tasks were diverse and the players had time pressure because the game format. The observers also reported that some of teams had a clear leader that delegated the work to other team members.

6.3. *Workshop activities*

The self-documentation and the workshop of the second trial provided additional means to look at the nature of the players learning practices while playing and designing games. The camera phones supplied in the second trial enabled the players to self-document as they played the game. Figure 8 shows a montage taken by the players. The 280 images taken by the 11 groups does a good job of illustrating the game from a more personal perspective of collaboration, physical activity, and how they used the mobile technology.

Based on the interviews, the time the players got for the workshops went by too fast for the girls when involved in designing the game. They would have liked to have more time to add other features in the design. For example, they suggested that with added time for design they could have integrated a film in the game. The combination of making up a story and creating assignments for the players is something that the girls say could be used in integrating different school subjects, such as physical education and social and science studies. As described by one of

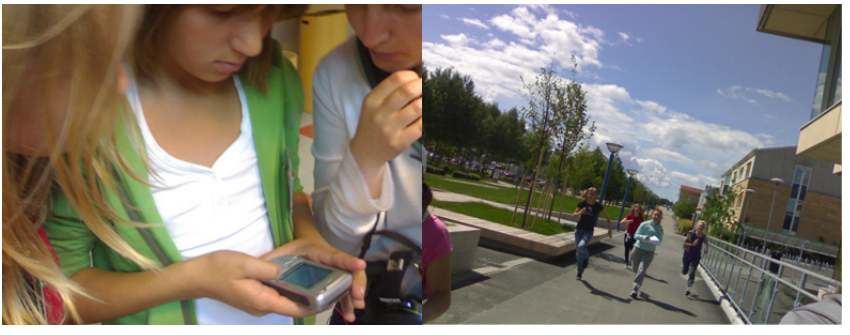

Figure 8. Self-documentation images.

the participants:

‘‘It would be interesting to challenge different schools to do this. In my sports class I get so sick and tired of always doing the same things, like playing different ball games.’’

6.4. *Results summary*

Exploring the different design practices has provided new perspectives beyond the data we collected from the surveys and interviews. By working with the students in the post game activities and through the design practices we could see how the players became more engaged in the activities by connecting the skills of making games to playing games. Figure 9 illustrates how different data were captured and used during the co-design process to guide the design and implementation of the different learning activities and versions of the game. This diagram shows also how the team, the games, and the evaluation approach evolved over the different versions of the game together with the co-design process. The fall 2007 activity presented a new game story and new features introduced by middle school students. Another local school played the game. Game play included photographic tasks with an additional mobile phone coupled to a Bluetooth GPS receiver that automatically uploaded geo-tagged images to the LAS and placed them into a Google map. The post-game reflective space generated from these photographs was also viewable as the game unfolded, allowing real-time observations of the game.

The preliminary indications of our results offer insights for exploring how informal mobile games could be integrated into traditional educational settings. This can provide ways to look at the learning practices of the students and provide authentic experiences in digital competence. The co-design process combined with methods like cooperative inquiry and learning by design, along with the rich offerings of existing human centric design approaches, offers an arena for innovation to the learning process and the opportunity to actively involve children in the learning process with mobile technology (2008).

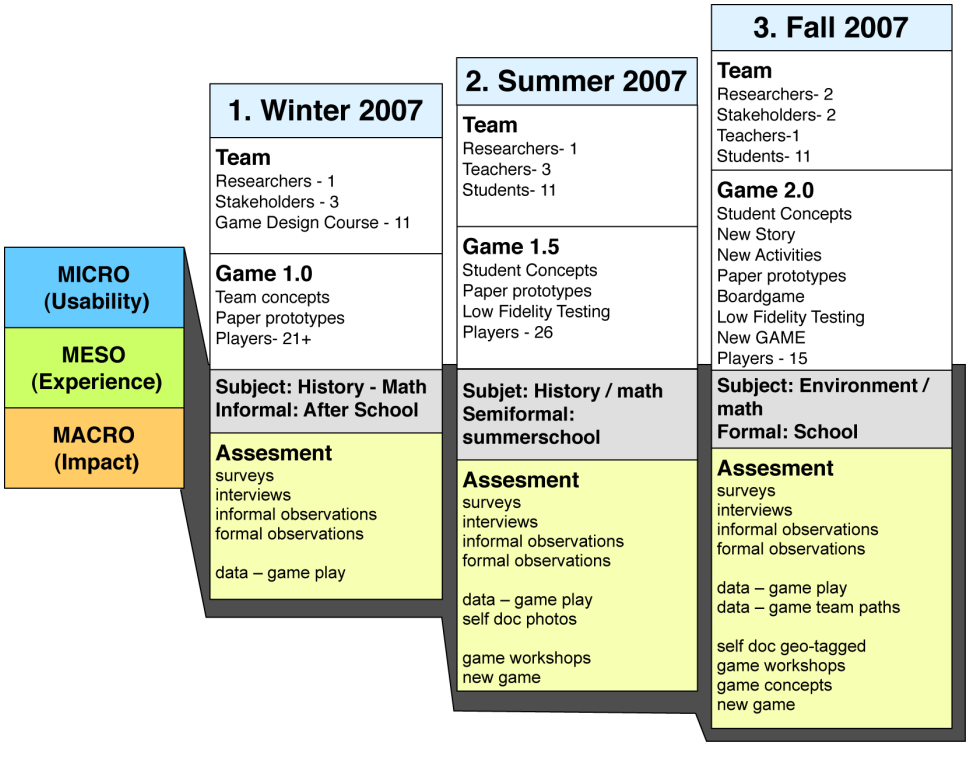

Figure 9. How co-design has been used across the different learning activities.

Additionally it can provide new insights to the design process by exploiting learners' new literacies in more formal contexts that can help them build critical awareness of game design and the other domains that the game is based on. Skattjakt has also illustrated the need for different evaluation practices for mobile-based games with informal learning that can accommodate different levels of collaboration across different learning contexts. Some of the benefits of mobile technologies, especially in the realm of contextual computing can help to provide tools to collect and organize data in new ways that may help us to understand, design, and evaluate these experiments from a wide variety of perspectives. The Skattjakt trials have also raised important questions regarding how to assess learning that takes place informally and across locations. Traditional methods for evaluation do not take into account these new learning situations (Vavoula & Sharples, 2008).

7. Discussion

Using the co-design approach together with mobile games for exploring new learning practices show some promises in dealing with the challenges of creating authentic and engaging activities that combine physical motion and gaming. Informal learning coupled with games can provide a foundation for innovation when applied to more

formal learning situations. This approach of combining mobile games as part of a bigger learning experience has provided us with a more authentic grounded experience than conventional learning activities conducted in classroom settings using traditional material such as textbooks or demonstrations of experiments. Jonassen *et al.*, (2002) point out that meaningful learning will take place when learners are engaged in authentic activities that allow for experimentation, conversation, collaboration and reflection. In contemporary learning theories, it is accepted that most knowledge can be seen as an interpretation of personal experiences that is social in nature. Therefore, knowledge is jointly constructed in interactions with artifacts, discussions with other peers and reflections upon concepts in a specific domain (Duffy & Cunningham, 1996). The context of how people collaborate with what tools, activities, and locations plays an increasingly important role when mobile devices enter the learning arena. Playful and active learning settings such as those described in this paper can help us to identify alternative ways of designing mobile learning tools and activities. Co-designing mobile games with learners provides the opportunity for students to get involved in activities that support experiential and inquiry learning through collaboration and to use new technologies and software tools that can support a wide variety of cognitive and social skills. In spite of these promising results, it is still premature to claim that this approach has contributed significant learning gains. More trials need to be conducted, combined with refined methods for data collection and analysis in order to start to evaluate the educational effects of this type of activity. As already stated at the beginning of this paper, the current focus of our efforts is mainly on design and innovative educational practices.

Overall, we can reflect that in terms of innovative educational practice Skattjakt has gone from an informal activity involving researchers and after school clubs to more formal settings of school based activities involving teachers and students designing and making new games. Rogers and Price (2006) point out that ubiquitous computing can offer the facility to integrate the outside informal learning that involves experiential and incidental learning with the formal classroom. Their focus is on integrating scientific inquiry, enhancing communication, and sharing and visualization of content. We agree with those views and offer a fourth perspective that focuses on actively involving the students into the design process for creating new activities. Recent development in this particular direction include a teacher from a local school together with the class playing the latest version of the game that has been designed by other middle school children last fall. These results will be briefly described in the coming section. From a game design perspective the results discussed in this paper provide a good foundation for further exploration of the research question that guides our work. The design-based research approach we have chosen provides opportunities to investigate phenomena in real-world settings, and it affords the ability to evolve the experiments to meet the demands of the users and the researchers to create innovation and expand theory. This approach has its limitations in terms of scientific validity and may lack in scientific rigor (Hoadley, 2004), but has provided us a good platform to create solid pilot studies.

As we mentioned in early sections of this paper, mobile technologies offer the potential for a new phase in the evolution of technology-enhanced learning, marked by a continuity of the learning experience across different learning contexts. Chan *et al.*, (2006) use the term *"seamless learning"* to describe these new situations. Seamless learning implies that students 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 their personal mobile 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, relatives, experts and members of other supportive communities, face-to-face or in different modes of interaction and at a distance in places such as classroom, outdoors, parks and museums. In the different cases that we illustrated in this paper, we developed several examples to implement the concept of seamless learning spaces by *augmenting physical spaces with information exchanges* as well as using *geospatial mappings* between the mobile device and the real world that facilitate navigation and context-aware applications. According to Pea and Maldonado (2006) these two latest features play an important role in designing mobile applications with an emphasis on inquiry processes, social constructivist theories, and distributed cognition designs.

8. Recent Efforts and Future Development

During the fall of 2007 and early spring 2008 we continued working with the co-design process in Skattjakt. We have worked together with a local junior high school with an elective class in physical education. The students have played the game and at this writing are developing new game concepts to implement and to be played with their classmates at the end of this year. For this trial, in addition to the game experience on the mobile phone we introduced photographic tasks for each one of the groups using a second phone paired with a GPS sensor. A Nokia N70 phone paired with a Bluetooth enable GPS device was used to take the pictures. We developed a mobile client using Python for S60 that connects to the GPS, providing location data to be stored with images in the repository. Additionally, images were tagged with IMEI to further support filtering. In the post activity the students, teachers, and researchers went over the game using components from the Presentation Engine to collaboratively discuss the results. Figure 10 shows an example of filtering the images collected during the game by group and location using the geo tags.

As the game experience progressed at each of the locations, the group was assigned a photographic task to be completed. As each group took photographs, these were automatically uploaded with geo-tags to our repositories and visualized on a Google map. The visualization was done in real time, thus allowing teachers and researchers to follow the different groups. We created a reflection space by utilizing the photographs mapped in real time to locations, enabling the students use the tools to discuss the game and photographic tasks. During the post-activity

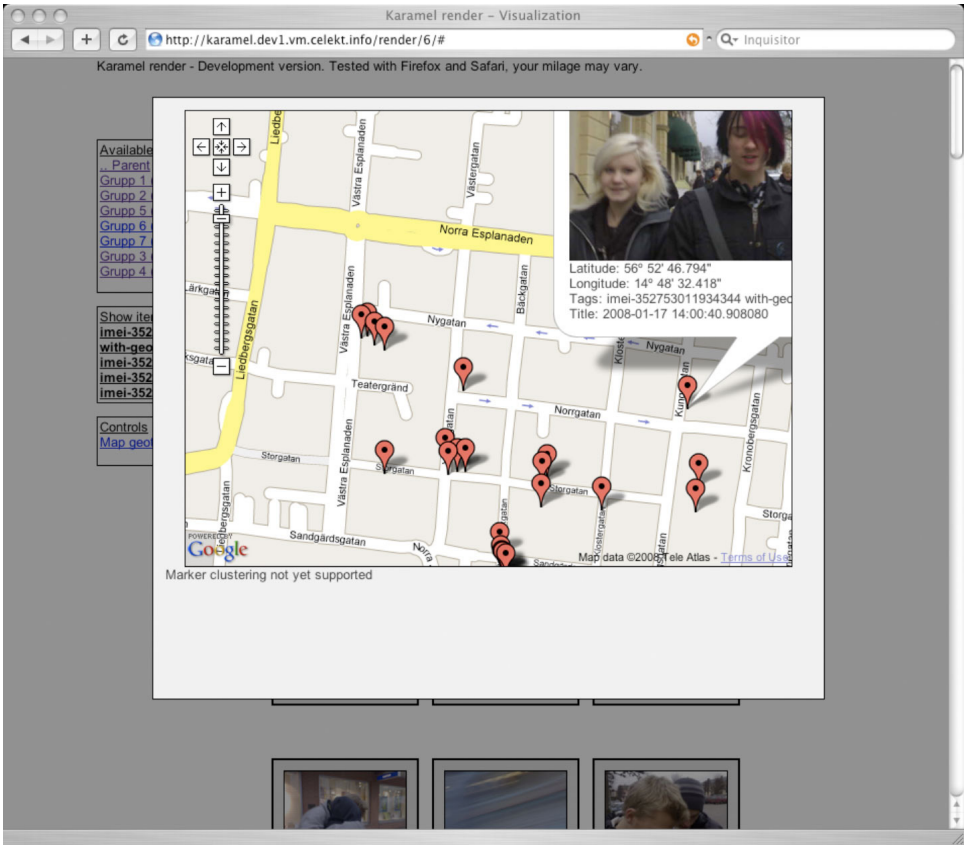

Figure 10. The post activity collaborative reflection space.

workshop the students and the research team gathered and reflected on the game and the photographs using the visualization tools.

From a technical perspective, we have developed a mobile application that provides automatic meta-tagging for the content created by each team that automatically add GPS coordinates to photographs, video, audio, and text created while playing the game. This latest feature allows for an automated cultural probe/self documentation tool where the rich media content created on the spot during the different activities can be stored in a repository for a later view together with other players. We are working now on the development of a simple authoring environment using a graphical interface that will allow for manipulation of the XML data that the game uses. In our future work we will explore how to add new features to the LAS system such as location triggered collaboration tools, as well as to expand the range of sensors, in addition to GPS and semacodes, to help make the process of data collection from the field tangible in the learning process. Another focus of our current research is the exploration of how to develop robust concepts and methods

for integrating contextual information as part of the metadata to be stored in our learning object repository (Svensson & Pettersson, 2008). The pre-determined metadata slots defined in learning object standards like the IEEE LOM (Suthers *et al.*, 2001) can be insufficient when describing the necessary contextual and environmental characteristics, such as group progress in activities, custom metadata tags and user-generated content.

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