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USING THE MOLES AND MINI MOLES SOFTWARE SYSTEM TO BRIDGE THE GAP BETWEEN INDOOR AND OUTDOOR LEARNING

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ABSTRACT

The present paper focuses on bridging the gap between inside and outside classroom learning experiences. We present Moles and Mini Moles, a learning software tools system specifically designed to serve this purpose. Secondary school students use these tools for hypothesizing, gathering, and transferring information learned within the classroom and testing their knowledge and recording their experiences in the physical environment outside their classroom. With Moles and Mini Moles, they create interactive multimedia questionnaires and explanatory material, document outdoor learning situations, and present their findings on the Web. We present data from evaluations of practical mobile learning project scenarios, which focus on cross-disciplinary subject material. The data indicates positive effects on various dimensions: using the learning software tools promotes collaborative work, problem solving skills, and organizational skills. Yet, the evaluation results also indicate pronounced gender issues and point out technological problems. An outlook on current and future developments of the Moles and Mini Moles learning tools concludes the paper.

KEYWORDS

Mobile learning, XML transfer, collaboration, evaluation

1. INTRODUCTION

Mobile learning applications in schools support students' exploration tasks in the physical environment outside their classroom. They encourage students to reflect, explain, and hypothesize about the physical world (Robertson & Good, 2004). These projects exemplify and augment the students' formal classroom learning experiences. In doing so, they comply with situated learning theory (Brown et al., 1989), which implies contextualization of learning

content (Lave & Wenger, 1991). Situated learning is one of the hallmarks of the constructivist view (Lave & Wenger, 1991).

At the University of Luebeck in Germany, the KiMM (Kids in Media and Motion) initiative (http://www.kimm.uni-luebeck.de) follows a constructivist/constructionist view (Papert, 1980), where the students actively and creatively use digital media (e.g., PDAs, digital video cameras, iconographic programming software) to create (multi-)media applications or systems. Most importantly, the students are primarily responsible for developing their projects from start to finish and handling these systems. This implies, for example, collaboration, organization, social interaction, and problem solving on the part of the students.

The KiMM initiative uses computers and other digital media as cognitive tools in a broad range of contexts. We support three general areas, which include interactive mixed-reality performances and installations, web cooperation and pervasive gaming, and mobile and ubiquitous learning (Winkler & Herczeg, 2005). The present paper addresses constructing innovative mobile learning projects in secondary schools (5^{th} to 13^{th} grades, students' ages 10 to 19 years old). We work together with teachers, developing project concepts based on the school's curriculum that require students to work in collaborative and self-sufficient learning environments (Melzer et al., 2005b). Projects encompassing the use of software tools and other digital media actively support and enhance the transfer of knowledge both inside and outside the classroom (i.e., digital augmentation; Rogers et al., 2005).

2. DEVELOPING INTERACTIVE MOBILE LEARNING PROJECTS

By using a collaborative work model, the students improve their problem solving and organizational skills (Melzer et al., 2005b). Thus, from the earliest stages of the project on, an important aspect of our concept stipulates that the responsibility for the project lies primarily in the students' hands. Experiencing the positive outcome of self-initiated activities eventually leads to a high level of self-efficacy, which in turn increases the individual student's learning motivation (Bandura, 1994; Robertson & Good, 2004). The benefits and advantages of students' early involvement in technologically oriented design processes based on participatory design have been demonstrated in related approaches (Guha et al., 2005). In a collaboratively oriented mobile learning model, the students' participation and learning begins in the classroom, extends outside of the classroom during a field trip, and is finally completed with a reflective presentation process in their classroom (e.g., sharing their gained knowledge with classmates).

The standard instruction model for school field trips bears the risk that teachers are the main benefactors of indoor/outdoor learning experiences. This is due to the fact that they research and prepare all information needed for the field trip themselves. The teachers carry out all the initial research, prepare extra explanatory material, plan the routes and then create the questionnaire for the students to use during field trips. The students, on the other hand, experience a gap between formal classroom learning and outdoor learning situations. They are not involved in the aforementioned interlinking activities. Thus, the contextualisation (or transfer) of classroom learning content is much harder for the students. In this regard, Rogers and her colleagues (Robertson & Good, 2004) concluded "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).

In our interactive mobile learning model (Figure 1), we address this issue in a closed-circuit loop approach. According to our model, the students' work starts in the classroom. They consider, with the help of the teacher, what topics in the school's curriculum are applicable for an upcoming field trip, and which possible scenarios are relevant. Finally, they have to formulate these ideas into a concept. The students then have to extrapolate how this information can be useful in a real life learning situation. This is reflected in the students creating so-called *testing kits*. Each testing kit comprises a collection of questions to test their acquired knowledge, as well as additional information, which they need during their field trip. This may include a series of tasks, reference and explanatory material, and/or route instructions. Thus, the resulting testing kit goes beyond the scope of standard (paper versions of) knowledge questionnaires.

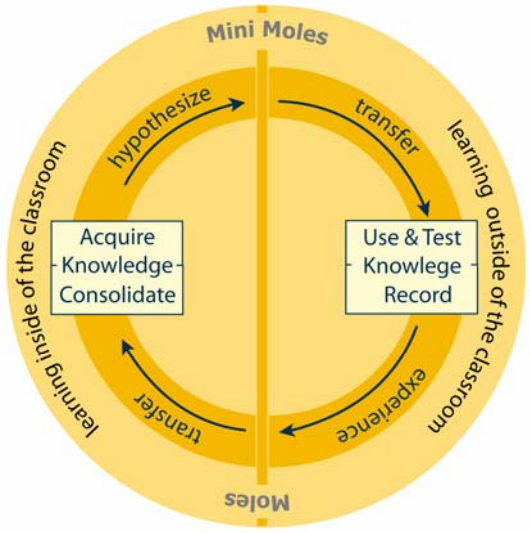

Figure 1. Moles and Mini Moles supporting acquisition and consolidation of knowledge by bridging the gap between inside and outside classroom learning

Outside of the classroom, during their field trips, the students collect data and record their observations in a manner guided and assisted by the knowledge they have previously acquired in the classroom. They also test whether the real life situation validates their hypotheses, which led to construction of the testing kit: are the questions that they formulated, the tasks that they defined, the explanatory information given, sufficient?

The students then return to the classroom and complete the documentation of their findings for later presentation. With regard to consolidation of learning, students need to reflect upon what they learned by presenting their finding either in the classroom or on the Internet to other persons interested in the project.

The teacher's role is primarily one of advisor and verifier of the project. The teacher and students define together the project content, methodology, and time frame at the beginning of the project. If there are any technical difficulties or if problems arise within the group, the

teacher assists the students in directing them towards a viable solution. The teacher also must verify whether the testing kits comprise all relevant topics and whether the information or data acquired during the field trip is valid.

This closed-circuit loop model illustrates the complexity of the requirements for mobile learning projects. Most importantly, it implies the need for seamless integration of hardware and software system tools. Moreover, software systems evolving from the above-mentioned closed-circuit loop model will support the premise that mobile learning means making the *acquisition* and *transfer* of formal learning mobile. Software tools devoted to mobile learning should feature a high degree of interconnectivity, thus providing a pervasive environment for learning, a concept Rogers and her colleagues called "Ubi-learning" (Rogers et al., 2005). This is in sharp contrast to the "anytime anywhere" approach found in some e-learning concepts, which simply promote the idea that the learner be independent from a specific geographical location.

The KiMM initiative set a goal to design and develop software tools, which were conceived to mirror the functionality of Ariadne's Thread in the Greek mythology, thus guiding the students through all phases in the above-mentioned work model. Our mobile learning exploring system tools, *Moles* and *Mini Moles*, are described in the upcoming section.

3. MOLES AND MINI MOLES

The software tools Moles and Mini Moles support projects whose emphasis is on students working in groups, creating future outdoor learning situations (e.g., field trips). First, the students research and create content for digital multimedia testing kits on PCs (Moles), which contains all needed instructional and explanatory information, and knowledge questions. Each testing kit is then transferred onto PDAs (Mini Moles). During their outing, the students record their observations and findings in the PDA and answer questions. They use other digital media (e.g., data measurement sensors, digital photo camera, GPS) as well. Their findings are transferred back into Moles (PC) for Web-based presentation.

Teachers and students (i.e., end users) worked closely together with the KiMM software developer throughout the entire software development lifecycle. This included design, production, and evaluation phases. The motivation behind this was to assure that the end product would not only be usable in a large variety of schools and learning scenarios, but also be compatible with technological systems currently available in these schools. Therefore, innovative and promising hardware-based solutions (e.g., Sharples et al., 2002), or cost intensive systems (e.g., Terrenghi et al., 2004), were out of the question.

With regard to the software, various powerful systems have been proposed that address the issues mentioned above (e.g., *DataInHand*™; http://datainhand.wfu.edu/). Unfortunately, they do not meet our requirements for the software tools to incorporate a wide selection of multimedia and interactive elements, and still be complex yet easy to use by students of different ages and heterogeneity in terms of computer literacy.

The system specifications for Moles and Mini Moles were as follows:

- comprise information previously learned in the classroom
- support the discovery of the physical world
- encourage collaborative work in small groups inside and outside of the classroom

- promote constructive and versatile use of different digital media (e.g. PCs, mobile devices, cameras, and sensors)
- incorporate a wide selection of multimedia and interactive information (e.g. audio, text, photos, sketches, links (HTML))
- take into consideration the severely limited financial resources of the schools and the fact that each school has access to different and often limited types of digital devices

These specifications resulted in Moles, a content management system, which runs on PCs, and Mini Moles, which displays data edited with Moles on PDAs (Figure 2). The Moles system was initially developed as a non-server-based system since the majority of schools have limited or non-existent PC networks and limited Internet access. For this reason, the data is generated on standalone PCs, using XML files and media files, and then transferred onto the mobile devices (i.e., PDA). After the field trip, the data from the completed questionnaire and other collected information is transferred back onto the PCs for final documentation and presentation.

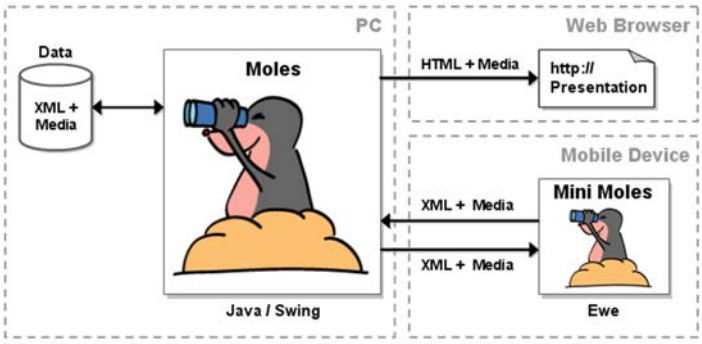

Figure 2. Moles content management system and Mini Moles data transfer for mobile devices

The advantage of using XML is that it structures the data objects, links easily to other media formats, and acts as an interchange format to and from Mini Moles. The DTD (Document Type Definition) defines the structure of the XML document (Figure 3). It is used to control and assure that the information being exchanged back and forth from the PC to the PDA complies with the predefined conventions.

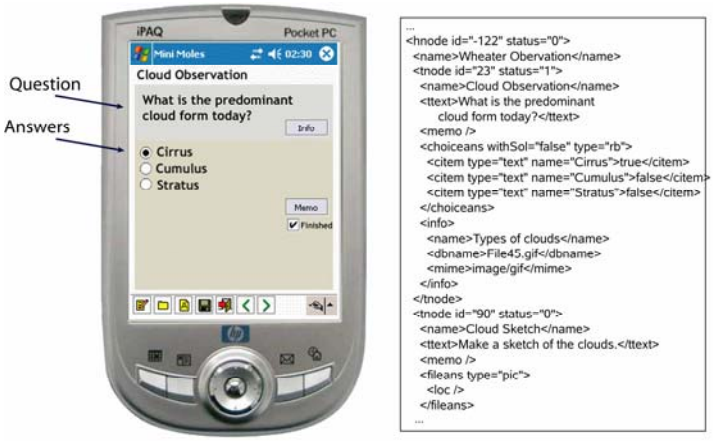

Figure 3. Mini Moles GUI on a PDA (*left*) and respective XML file extract (*right*). Please note that Figure 3 displays a translated screen, not an actual screenshot because Mini Moles is currently available only in German. However, there already exists an English version of Moles

The Moles and Mini Moles concept addresses three phases of development: *research and questionnaire production* (PC), *data entry* (i.e., record observations during the field trip on PDAs and other digital media) *and information access*, and *documentation and presentation phases* (PC).

Research

The XML-based Moles was implemented in JAVA. Moles allows secondary school students (5^{th} to 13^{th} grade) to create interactive multimedia testing kits on a PC using Moles' intuitive graphical user interface (GUI). The testing kits contain a pool of questions and the explanatory material needed for the upcoming outdoor learning situation or field trip. The testing kits are then transferred onto PDAs (Mini Moles).

Data Entry and Information Access

The JAVA-based Mini Moles is a software tool that transfers the previously edited testing kits onto PDAs. During their field trip or ubiquitous game, the students answer the questions and complete the series of tasks specified in the questionnaire. They use different sensors and measuring devices, as well as personal observations, to record findings in Mini Moles.

In addition, Mini Moles is used as an information source to access explanatory information and route instructions during the field trip. All this needed information (e.g., measurement procedures, background historical facts) is logically linked to the appropriate questions or tasks and accessed directly in the questionnaire on the PDA (Mini Moles; Figure 3 left).

Presentation

When the recorded information is copied back from Mini Moles into Moles and the extra data (e.g., photos) is placed into the finished document, Moles' GUI offers a web presentation function. XSLT files are used as style sheets to automatically export the XML-structured document into a HTML presentation.

4. CREATING MOLES AND MINI MOLES PROJECTS

The above-mentioned three phases of development and the functions and features of Moles and Mini Moles correspond to the respective activities.

In the research phase, the students create the testing kits (Figure 4). They research the topic of interest (assisted by the teachers). They provide photo, audio material, and sketches needed as explanatory information for the testing kits. All of this material is transferred into the media library in Moles (Figure 4: step 1) using the Windows™ file browser. Next, the students create a non-ordered pool of content (Figure 4: step 2). This includes the following activities:

- creating new folders
- deciding which type of question format is appropriate for each question (e.g., multiple choice, singular or multiple texts, audio, photo and sketch),
- formulating and typing in their questions in a pop-up window (e.g., Q: What is the predominant cloud form today? A: Cirrus, Cumulus, Stratus)
- inserting extra explanatory information (e.g., text, audio, links, photos, or sketches) as needed, and
- selecting and inserting the respective map or routing information

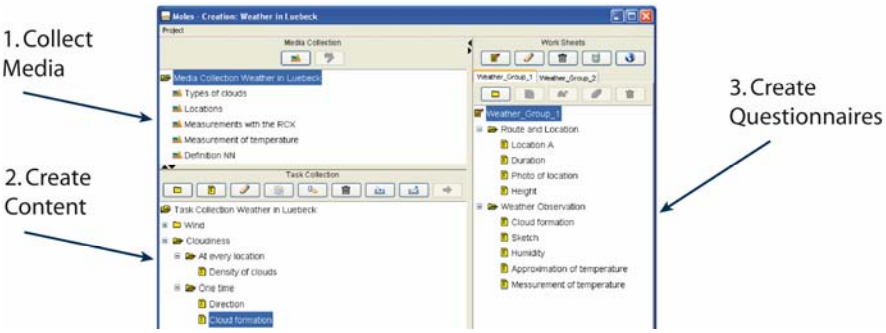

Figure 4. Moles graphical user interface on PC

Finally, questionnaires (testing kits) are constructed by extracting and rearranging items from the pool of content (Figure 4: step 3) for each respective group. The reason for this is that each group on the field trip is likely to take a different route or to answer a different series of questions, as well as the collect and record different data. The teacher verifies the resulting testing kits, which are then transferred to PDAs (Mini Moles).

During the field trip the students record measurement data, observations, and impressions into the Mini Moles GUI on their PDAs. They also use other measurement and recording devices (e.g., air pressure and humidity sensors; see upcoming section). When their field trip is over, the completed Mini Moles data files from each PDA, as well as any information or photos taken on other devices, are copied back into Moles (i.e., PC). The teacher then checks the answers for correctness. In the final project phase, the complete information in Moles is automatically converted into HTML format for web presentation.

5. USING MOLES AND MINI MOLES IN A PROJECT SCENARIO

The subject material of our mobile learning projects is derived from the individual class curriculum and elaborated in close cooperation with the teacher (Melzer et al., 2005a, b). In most of our projects, an emphasis is also placed on cross-disciplinary work, thus incorporating a broader scope of subject material into the projects. Here follows brief descriptions of three project scenarios using Moles and Mini Moles.

- In the first 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 (Melzer et al., 2005b). The students researched and used material acquired from three class subjects (geography: weather elements, mathematics: diagram systems, and physics: measuring systems and sensors) to create interactive multimedia questionnaires (Moles). The 7th graders participated in a field project day measuring and recording weather information at five different "weather stations" distributed throughout the city (Mini Moles).
- In the second project, mentoring students (10th grade) created a *Mobile Advent Calendar*, an ubiquitous game, for the first year high school students (5th grade). The 10th graders were responsible for planning the project, creating testing kits (Moles) and organizing the daily event during Advent. The 5th graders, new to the school and unfamiliar with the surrounding neighborhood, went on a digital treasure hunt inside and outside the school to discover the "door" 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 third project is called *Children, Children!* In this museum/school project, the 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 blogs were a collection of written stories, drawings, photos, music sequences, and links to related material the students studied and recorded. The students then used this material to create an ubiquitous history hunt with Moles and Mini Moles. The ubiquitous game (on PDAs) was played at 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.

In the next two sections, we will present the lessons learned from these project scenarios that used the Moles and Mini Moles software system. The discussion of projects' evaluation results will focus on the pedagogical issues and technical issues, respectively.

6. PEDAGOGICAL ISSUES: LESSONS LEARNED

We have presented a detailed analysis of the pedagogical success of the *Mobile Weather Project* elsewhere (Melzer et al., 2005b). Not surprisingly, comparison of students' pre- and post-project ratings indicated a higher level of general computer expertise after the class project. Accompanying the general acquisition of media literacy, the students also reported a stronger positive attitude towards the use of digital technology in schools. For the *Mobile Advent Calendar* project, we observed substantial positive effects on the cognitive level. This

refers to increases in spatial knowledge and orientation (both in the self-reported data and the teachers' estimations), and social interaction, respectively.

In the *Children, Children!* museum/school project, 25 students (10 boys and 15 girls) and two teachers were evaluated after completing the history hunt game. The students received a questionnaire (29 questions) that focused on whether they were able to complete their tasks using the digital media, their level of confidence using this media, the group communication and task allocation, and whether their expectations concerning the use of digital media were satisfied. The teachers' questionnaires (34 questions) contained parallel questions, but also their perception of the students' overall learning experiences. Table 1 presents selected items from these questionnaires).

The first item illustrates that the students found it easy to use the devices and the software tools. This perfectly matches the teachers' impression of the students' handling of the tools. Likewise, both groups agreed on the applicability of mobile devices in future school projects. In addition, using mobile devices did not interfere at all with the perceived joy of working in groups.

However, there was a remarkable difference between the teachers' and the students' ratings concerning digital devices becoming an integral part of future museum/school tours. We may only speculate whether the teachers' lower enthusiasm is due to them not fully realizing how attractive these devices are in the students' eyes, or whether they have a more realistic view about how challenging it is to constructively integrate the use of digital media inside and outside the classroom.

Table 1. Selected items from the *Children, Children!* project evaluation questionnaire, together with mean ratings. Ratings ranged from 1="*I don't agree at all"* to 6="*I totally agree"*. (Standard deviation presented in parentheses. See text for further details)

Item	**Students**	**Teachers**
PDA/smart phone/Mini Moles were easy to use	4.52 (1.24)	4.50 (0.71)
Mobile devices should be used more often in schools	4.88 (1.27)	5.00 (1.41)
I/They liked working in a group throughout the project	4.96 (0.82)	5.00 (0.00)
The museum should offer the history hunt using digital media	5.50 (1.32)	4.50 (0.71)
History hunt in the castle would have been interesting even without digital media	2.63 (1.66)	3.50 (0.71)

Finally, the last item of Table 1 shows another discrepancy between students and teachers. As suggested by the high standard deviation, another factor is likely to have affected the students' ratings. A close inspection of the data revealed that this was due to the same gender issues we have already observed in other projects. These differences exist between male and female students in terms of emotional, cognitive, and behavioral levels. To illustrate this, Table 2 presents the 'High 3' items that students most strongly agreed on, and the 'Low 3' items that students least agreed on for both male and female students, respectively.

Table 2. Male and female students' 'High 3' (*upper half*) and 'Low 3' (*lower half*) item texts in the questionnaire that received highest and lowest mean ratings (*M*), respectively (ratings ranging from 1="*I don't agree at all"* to 6="*I totally agree"*). (Standard deviation presented in parentheses.)

Male Students	***M (SD)***	**Female Students**	***M (SD)***
The museum should offer the history hunt with digital media	5.80 (0.63)	I liked the history hunt very much	5.60 (0.74)
Handling PDA/smart phones /Mini Moles was easy	5.56 (0.73)	I liked the Children, Children! project very much	5.60 (1.07)
Instructions for PDA/smart phones/Mini Moles were sufficient	5.11 (1.17)	Now I know what it was like for kids to live in the past times	5.43 (1.16)
Running the project would have been interesting even without digital media	1.40 (0.70)	I would have preferred working on my own in this project	1.43 (1.09)
The history hunt in the castle would have been interesting even without digital media	2.10 (1.37)	I would have preferred doing the history hunt alone	1.57 (1.45)
I would have preferred working on my own in this project	2.40 (1.51)	There were too many students in the workgroup	2.21 (1.48)

The 'Highs & Lows' item list illustrates how the use, or even the promise of use, of digital media acts as a motivator for boys to work enthusiastically in collaborative projects. In sharp contrast, the girls' main motivator for working in collaborative projects is the project *itself*, that is, its content, and the promise of social exchange. Though a fully fledged analysis of the gender issue would go beyond the scope of this paper, we conclude that gender-specific expectations exist and they have to be considered in the preparation of school projects using digital media.

Besides the aforementioned results obtained from the *Children, Children!* museum/school project, other evaluation results indicated specific negative or unwanted effects in the practical implementation of the collaborative work model. For example, the students initially found it difficult to come to collective decisions and to delegate tasks. This led to redundancy and, thus, an inefficient work process. Rather than dividing up the tasks, the students tended to accompany each other on the tasks: very often one person was doing the work and the others were purely bystanders. This problem (which is likely due to the frontal instructional form most prevalent in German schools) was addressed by requiring the students to keep a written protocol of who was to complete which task when.

We also observed that introducing digital media intensified rather than resolved certain inequalities in group dynamics (i.e., gender related monopolizing of attractive media and material; Melzer et al., 2005b). This requires that both teachers and KiMM team members continuously and carefully supervise the different groups. In addition, students have to develop a general awareness that certain unwanted effects may occur that need intense communication and collaboration within work groups. Finally, throughout class projects, the students reported that they found it difficult to accept the fact that they would not be given a

chance to use all the digital devices. Hence, the disadvantage of not having enough digital devices for all students requires adequate management of resources. This may only be achieved through improvement of communication and problem-solving skills.

7. TECHNICAL ISSUES: LESSONS LEARNED

With respect to the technical realization, Moles and Mini Moles software tools offer the following advantages over other systems (*DataInHand*™, http://datainhand.wfu.edu/; Sharples et al., 2002; Terrenghi et al., 2004): they are usable in a large variety of school learning scenarios, yet may be used on the computer systems currently available, they incorporate a wide selection of multi-media and interactive elements, they are complex but easy to use, they are cost effective, and, unlike other prototypes, have been empirically tested and proven fruitful (Melzer et al., 2005b). In addition, Moles and Mini Moles meet the system requirements specified in Section 3. However, a specific usability issue, automatic and manual positioning, and the need for extending the system's communication functions became apparent.

With regard to the usability issue, the GUI turned out to be sub-optimal for students younger than 7th grade (age 12 and below). Hence, we developed *Moles-for-Kids*, which has an intuitive GUI (programming with icons) and can be used in mobile learning projects from elementary schools grades upwards.

Secondly, teachers needed assurance 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. To address both issues, we designed and developed *Mini Moles LOC* (loc: location; Figure 5). This tool allows the students to access ("unlock") the information contained in the Mini Moles questionnaire pertaining to their current location only if their actual position is correct. The GPS coordinates can be entered automatically (e.g., attached GPS unit with a PDA interface) or manually (GPS handheld unit). Alternative, it is also possible to manually enter pre-determined code names to unlock information. *Mini Moles LOC* with automatic positioning sensing system tracks the current location of the user and shows them how to get to the next location.

Entering GPS coordinates or code names, especially if the names are derived from physical indicators (e.g., building addresses or exhibit numbers), turns the whole project into a Geogame format. This enhances the students' learning experiences by combining educational content with location-based information systems and the physicality of their environment (Kiefer et al., 2006).

The last technical issue that requires improvement concerns inter-group communication during the school outings. The planned wireless data transfer in *Net Moles* will establish a sense of social awareness and collaboration between different work groups. Thus, *Net Moles* will represent a form of communication-oriented computer-supported mobile learning (Sharples et al., 2002).

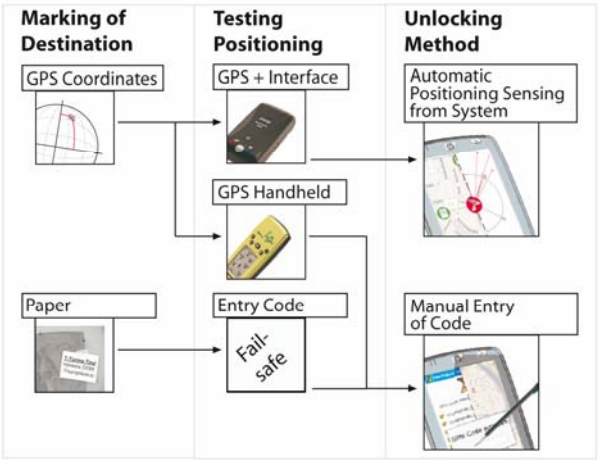

Figure 5. Two marking possibilities for establishing location or position with *Mini Mole LOC*

8. CONCLUSION

In addition to the cognitive and work group effects reported in the latter section, the applicability and usability of the Moles and Mini Moles software learning tools were evaluated in each class project. The evaluation data clearly indicated the overall success of the project scenarios that were designed and realized within our approach of bridging the gap between indoor and outdoor learning (Melzer et al., 2005b).

The challenges faced developing mobile and high interactive learning projects are numerous, yet not insurmountable (Melzer et al., 2005b). Positive effects on self-esteem and the promotion of learning performance in school (Winkler & Herczeg, 2005) make such projects desirable. The benefits for students are apparent in an increase in their motivation and the efficient and intense acquisition and transfer of knowledge.

Transforming theoretical knowledge acquired in classroom studies into accessible, real, and practical tasks for outdoor learning is a challenge. By supporting contextualisation of the learning content, the Moles and Mini Moles software tools meet this challenge, acting as a guide inside and outside the classroom, not unlike Ariadne's Thread in Greek mythology that provided its inexperienced users with safe navigation through an unknown labyrinth.

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